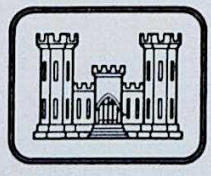
WATERPOWER '79

an international conference on small-scale hydropower

October 1-3, 1979

EXECUTIVE SUMMARY

U.S. ARMY CORPS OF ENGINEERS



U.S. DEPARTMENT OF ENERGY

CONFERENCE CO-CHAIRMEN

Lt. Gen. J.W. Morris, Chief of Engineers, U.S. Army Corps of Engineers
George S. McIssac, Assistant Secretary, Resource Applications, U.S. Department of Energy

STEERING COMMITTEE

Brig. Gen. Hugh Robinson, Chairman, Deputy Director, Civil Works, U.S. Army Corps of Engineers
James R. Hanchey, Acting Director, Institute for Water Resources, U.S. Army Corps of Engineers
Richard McDonald, Resource Manager, Hydroelectric Program, U.S. Department of Energy
Alex Shwaiko, Chief, Planning Division, Office of the Chief of Engineers, U.S. Army Corps of Engineers

TECHNICAL PROGRAM COMMITTEE

David Zoellner, Chairman, Institute for Water Resources, U.S. Army Corps of Engineers
Margaret McClements Lambie, Small Hydroelectric Resource Development Program, U.S. Department of Energy
Sharon Blake, Institute for Water Resources, U.S. Army Corps of Engineers
Lu DuCharme, Office, Chief of Engineers, U.S. Army Corps of Engineers
Darrell Nolton, Institute for Water Resources, U.S. Army Corps of Engineers

WORKSHOP PROGRAM COMMITTEE

Margaret McClements Lambie, Chairman, Small Hydro Program Staff, U.S. Department of Energy
David Auslam, President, Auslam & Associates
Peter Brown, Energy Law Institute, Franklin Pierce Law Center
Ralph Burr, Small Hydro Program Staff, U.S. Department of Energy
Ronald Corso, Federal Energy Regulatory Commission, U.S. Department of Energy
Stephen G. Hildebrand, Oak Ridge National Laboratory, U.S. Department of Energy
Robert Philleo, Engineering Division, U.S. Army Corps of Engineers
George Smith, Idaho National Engineering Laboratory, U.S. Department of Energy
Edward Tanzman, Argonne National Laboratory, U.S. Department of Energy
David Willer, Head, Water Resources Program, Tudor Engineering Co.

PARTICIPATING ASSOCIATIONS

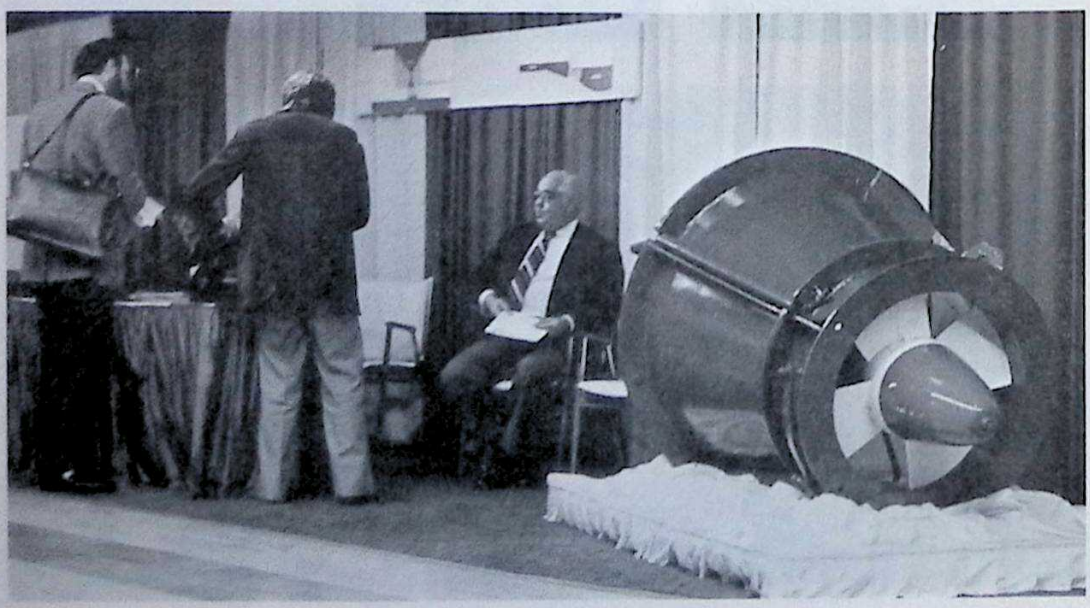
Institute of Electrical and Electronics Engineers, Inc.
National Society of Professional Engineers
American Society of Civil Engineers
American Society of Mechanical Engineers
Society of American Military Engineers

CONFERENCE PLANNING AND MANAGEMENT SUPPORT

International Science & Technology Institute, Inc., Washington, DC

WATERPOWER '79

EXECUTIVE SUMMARY



I. CONFERENCE PROFILE

Waterpower '79 was held October 1-3, 1979 at the Washington Hilton Hotel, Washington, D.C.

PURPOSE

The purpose of the conference was an exchange of information among those in the public, private and international sectors who are either actively working in hydropower or have a strong interest in the subject.

ATTENDANCE

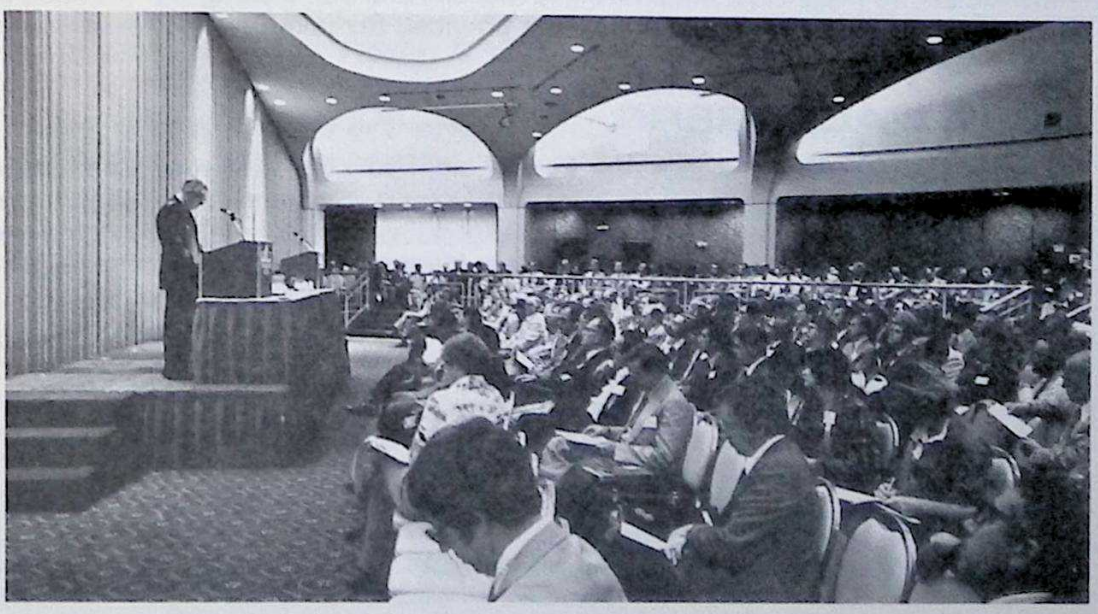
The attendance exceeded 1200 and included representatives from many sectors—Federal Government, State and Local Government, Architect-Engineer firms, financial institutions, utilities, associations, U.S. and foreign manufacturers, universities, international organizations, foreign countries, and many others

TECHNICAL PROGRAM

The technical program consisted of: a White House executive address; plenary sessions dealing with topics in engineering, policy, planning and international experiences; two special Congressional addresses; twenty-three technical sessions in which eighty-nine papers were delivered in topics ranging from social, economic and environmental concerns to innovation, facility design and international assistance; thirty-two exhibition booths and a film and slide theatre; and workshops which were offered on a repeating basis and dealt with topics on financing and marketing, planning, development policy and legal context, government funding, licensing, engineering, dam inspection, and environmental issues.

SPECIAL EVENTS

An exhibitors' reception with canape's and drinks in the exhibit hall, a Congressional reception for 1200 - 1300 was held on the Hill and catered by the Senate caterer, and a conference luncheon was held featuring as guest speaker, the Chairman, Hydraulic Resources Division of the World Energy Conference Commission on Energy Conservation.



II. CONFERENCE FINDINGS

POTENTIAL

There is considerable potential for hydropower development via upgrading, retrofit and new work in both the U.S. and other countries.

- U.S.—Northeast, Southeast and Lake Central areas have the most potential with roughly 5,000 MW at 4,800 sites, most of which are in New England.
- Examples of countries that are actively installing and/or inventorying small-scale potential include, New Guinea, Peru, Peoples' Republic of China, and others.

METHODOLOGIES

Technical methodologies have been and are being developed at universities, research institutes, regional, federal and state government agencies in such topics as hydrologic and hydraulic based feasibility assessments, computer assisted techniques for inventories, modeling and various approaches to environmental, economic and social assessments.

INTEREST

The interest in small-scale hydropower is part of the larger interest in technologies utilizing renewable energy resources. The large conference turnout of over 1200 when 700 were expected, the large number of international requests for conference proceedings, the heavy attendance at DOE regional workshops in hydropower, the formation at WATERPOWER '79 of a professional society of small-scale hydropower, and the inundation of FERC with license applications and requests for information all indicate a growing interest in small-scale hydropower.

ROLE

The role for hydropower in the future while not a major energy supply is an important one. Relatively inexpensive energy, minimal environmental damage and the ability to provide large centralized as well as small decentralized power will help our energy supply system.

This role has been assured by both the Administration as well as the Congress. Recent initiatives from the President are designed to provide hydropower to rural America and to install low head turbines in locks and dams along the Mississippi River. Legislation from the Congress has provided tax incentives for developers.

MANUFACTURERS

Vendors are continuing to develop new equipment appropriate to small-scale hydropower. Turbines are being marketed which are designed for low flows, low heads and have standard sizes. Breakthroughs lowering power house costs are continually pursued. U.S. manufacturers are competing in the world market, but they must also compete with foreign manufacturers at home.

CONFERENCE CO-CHAIRMAN

LTG JOHN W. MORRIS
Chief of Engineers
U.S. Army

"Since 1900 we moved across the country from coast to coast like a giant machine harvesting the choice hydropower sites."

"Hydroelectric power development at many dam projects which had not been economically feasible in the past, have suddenly become attractive investments."

"We are now retracing our steps, gleaning the potential power sites we overlooked before the escalating cost of fossil fuels made hydropower more competitive."

"There are five Corps power projects under construction which will have an installed capacity of almost 1.4 million KW. Four power projects now in operation have authorized power additions. There are 9 power projects authorized, but not yet under construction. Nine existing power projects will require authorization to install additional units. Fifty existing projects have potential for installation of power generating units. Finally, 35 potential projects not yet authorized have a power potential greater than the Corps current installed electric capacity."

"The development of all of these potential sources of hydropower would more than triple the current generating capacity at Corps projects."

"We have been working closely with the Department of Energy as this jointly-sponsored symposium shows. We are developing the data base on which a sound national hydropower development program can be planned and executed. The cooperation of many Federal, State and local interests is essential to the achievement of that goal."

"The Corps of Engineers has the organization and capability to interface effectively with the private sector in the development of water resources, including hydropower. Its network of field offices reaches all sections of the country. The Corps is used to working effectively with State and local officials and individuals in its many programs involving planning, cost sharing, public participation and regulatory functions. Our track record for obtaining the cooperation of the public and private sector is a good one. I pledge the full cooperation of the Corps in the development of our total national hydropower potential."

CONFERENCE CO-CHAIRMAN

GEORGE S. McISSAC
Assistant Secretary for
Resource Applications
U.S. Department of Energy

"The most urgent aspect of the energy problem is our over dependence—I think of it as an addiction—to oil, particularly imported oil."

"We still must provide energy to support our industrial base and provide for the legitimate needs of our people. Thus, we must develop alternative sources of energy."

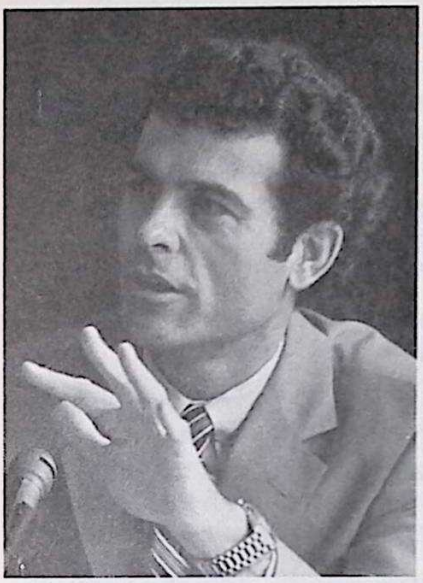
"This is the context in which we view small hydro. It is an available source of energy that has not been fully exploited. . . . It is reasonably economic, environmentally benign and directly applicable to power generation. It is part of the solution."

"There are four impediments to the widespread use of small-scale hydropower. These are: (1) lack of knowledge about the size, location and nature of the resource base; (2) lack of understanding of the pricing aspects of small-scale hydropower; (3) lack of proof, through actual demonstrations, that modern small-scale hydro technology works; and (4) difficulty of transferring information to potential decision makers."

In order to overcome these barriers, DOE has structured a four-part program:

1. *Special studies:*
   - *impediments to development and incentives for power-on-line*
   - *national assessment of small-scale hydro*
   - *state surveys*
   - *technical overviews*
   - *cost reduction and extended technology*
   - *implementation of state hydro legislation*
2. *Grants for feasibility studies and licensing assistance*
3. *On-going and planned demonstration projects*
4. *Regional informational workshops and developing user documents.*

EXECUTIVE ADDRESS



JACK H. WATSON, JR.
Assistant to the President for
Intergovernmental Affairs and
Secretary to the Cabinet
The White House

"The energy challenge, I think, poses some very fundamental questions to us . . . it poses questions about our capacities to respond to change, to discipline ourselves, our capacity to be a generation of Americans and citizens of the world on the . . . cutting edge of an era, the outlines of which we cannot, do not perceive yet."

"We have a kind of mega solution syndrome in a time in which there aren't any mega solutions. It's a syndrome from which we must escape."

"We need to do many things in the energy area, things of a dispersed nature that need to be done by local communities, with local initiative, for local pay-off . . . I am predicting, I think absolutely safely, that our attention has turned, and will continue to turn, to the smaller scale effort."

". . . They involve no new environmental impacts, generally speaking.
. . . They are virtually non-polluting.
. . . They are using a renewable resource.
. . . They are small and, almost invariably can be aesthetically acceptable, even pleasing.
. . . The technology for the hydroplants is established.

"Part of the benefit which I hope will result from a conference and other conferences like this one will be an exchange of expertise and technical knowledge with respect to the standardization and mass-production of that small scale hydroelectric power generation."

"It's interesting to note, and important I think, that A.I.D. in this country as well as the international finance community at large are recognizing increasingly the potential for small-scale hydropower and they are expressing interest in participating in the implementation of projects identified in those assessments."

". . . This energy crisis . . . gives us a chance to reexamine, at a pivotal moment, just exactly what kind of legacy we want to leave to our children and their children."

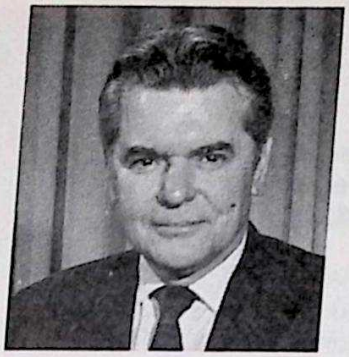
III. THEMES & TOPICS

A number of themes with key topics were woven through the conference fabric. The general conference spirit was one of optimism.

- engineering is meeting the challenge with such items as turbines requiring no dam, turbines designed for low head, standardized sizes, and so on.
- incentives are beginning to be developed through legislation for licensing exemption for facilities with small size and special purpose, for ownership transfer and for government subsidies through grants, loans and low tax rates.
- government planning programs are identifying opportunities through many state activities and Federal programs in the Corps, Water and Power Resources Service, Water Resources Council and others.
- problems exist, but are being identified and dealt with—environmental mitigation costs, financial assistance, marketing, powerhouse costs, for example.
- demonstration projects show where problems will occur, but also show it can be done in the case of new equipment, ideas, etc.
- many countries have much to offer either in the way of experience with small-scale hydropower or in potential for development.
- many analytical techniques exist or are being developed for planning, inventories, field surveys, economic assessments, hydrologic potential, environmental impacts, and so on.
- financial opportunities exist through the private sector also, via long term loans, and low interest rates to individuals and companies.

IV. TECHNICAL PROGRAM

Engineering



PLENARY

". . . small hydroelectric development is not only an idea whose time has come, but is also a practical and feasible energy development whose time has come."

NORMAN M. CLAPP
Former Administrator
Rural Electrification Administration
U.S. Dept. of Agriculture

There is considerable encouragement in the size of the total small-scale potential available. Of 54,000 dams surveyed the Corps found that roughly 10 percent, 5,424 sites, were technically feasible. Preliminarily, the capacity of these sites has been put at 94,636 MW.

DOE demonstration sites are also showing encouraging feasibility results. Of 54 studies, 60% were found to be feasible, though many were marginal. Facility costs generally ranged from $1000 to $2500 per kilowatt and energy costs from 20 to 45 mills. Additional demonstration projects are underway, with an expanded loan program for feasibility studies and licensing costs. Recent program opportunity notices have gone out seeking proposals for both larger scale demonstration studies as well as innovative demonstration projects.

Currently pending legislation would, if enacted in present terms, provide tax credits for small hydro facilities at existing dams of 25 MW or less capacity, including added investment tax credits for fish ways, transmission facilities, turbines, and civil works. It would also permit accelerated depreciation on small hydro facilities.

PANEL

Howard A. Mayo, Jr., *Marketing Development, Allis-Chalmers Corp.*
David C. Willer, *Manager, Water Resources, Tudor Engineering*
Robert H. Bruck, *Chief, Electrical & Mechanical Branch, Engineering Division Corps of Engineers*
William Love, *Superintendant of Utilities, Vanceburg, Kentucky*
William Lawson, *Director, Office of Technology Assessment and Forecast, U.S. Patent Office*

PAPER SESSIONS

Equipment — *small hydropower equipment for development and operation.*

Redevelopment — *existing facilities, historic sites — planning and structural considerations, application of "Mini Units", dam safety, retired plant potential and minimizing capital costs.*

Generation systems — *power station operation, equipment and new developments.*

Hydraulics and hydrology — *techniques for investigation, planning, design and problem analysis.*

New ideas, concepts and technology — *low velocity water currents, hybrid power plants, site built components and new applications, identification of research, hydraulic ram, hydropower without dams, appropriate technology.*

Development and operations economics — *busbar costs, evaluation of small-scale plants, conceptual run of river model and comparative project economics.*

Planning, Information and Methods

PLENARY

"Low-head hydro could conceivably produce all of the energy necessary by electric cooperative systems in this country to 1995."

ALEX P. MERCURE
Assistant Secretary for Rural Development
U.S. Department of Agriculture

In the past several years there has been tremendous growth in small communities in rural America. According to demographers, small towns are now growing, generally about twice as fast as our big cities. There has also been a tremendous diversification in the location of America's industry and REA is an important, though not exclusive, element in that development.

If, for their $10 million, DOE was able to finance only 100 demonstration plants which averaged 5 MW, they would produce a total capacity of 500 MW. In REA, 500 MW of capacity would represent $500,000,000 in loans. That gives some idea of how important it is to aggregate these diverse sources of energy.

It's time to think about what small units aggregated and dispersed could do—it isn't difficult for REA to integrate small quantities of electricity, particularly if it's baseload, into the transmission systems that those electric coops already have. Small irrigation diversion dams and larger erosion control dams have power producing potential.

The coops are beginning to show an impressive initiative not only in hydropower, but in a range of several solutions to help capture the waste of energy.

PANEL

Robert Cross, *Administrator, Alaska Power Authority*
Ronald Corso, *Deputy Director, Licensed Projects, Federal Energy Regulatory Commission*
Jerry D. Priscolli, *Sr. Social Scientist, Institute for Water Resources, Corps of Engineers*
Mike Spear, *Associate Director, Environment, U.S. Fish & Wildlife Service*

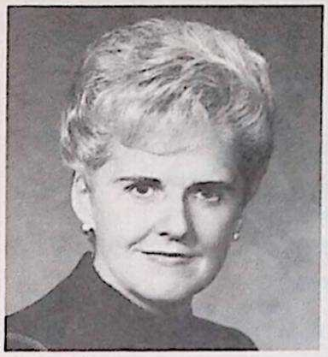
PAPER SESSIONS

Social and Environmental Analyses — *community impacts, historic preservation, fish passage technology, employment possibilities, assessment methodologies, water level fluctuations and institutional arrangements.*

Planning for development — *inventories, resource assessment, screening methodologies and statewide coordination, planning hydro additions, financial planning, state planning and optimizing feasibility studies, factors affecting feasibility, mapping systems, evaluation models and supporting services.*

Case studies and demonstration projects — *feasibility investigations, innovative state legislation, powerhouse reconstruction, unit size selection, tidal power, power projects and preliminary feasibility studies.*

Policy



PLENARY

"Clearly, small-scale hydropower can play a major role in a short term solution of our energy needs. And it must be a vital part of our long term energy program."

GEORGIANA SHELDON
Commissioner
Federal Energy Regulatory Commission

The Commission has made recent efforts to simplify and expedite the licensing process. In September of 1978 the FERC simplified the licensing procedure for power projects with a capacity under 1.5 MW which lessens detail and information required, and revises comment procedure. In March 1979 requirements were put forth which simplified filing related to amendments, cancellations and reducing exhibits from 9 to 4. In April 1979 procedures were proposed which streamlined the processes at existing sites, reducing exhibits from 23 to 7. A final phase of reform in FERC licensing will apply to new projects of capacity greater than 1.5 MW.

In April 1979 FERC exempted licensing requirements of projects 15 MW or less located on man-made conduits for generating power only.

Some 17 different federal statutes have vested various federal agencies with jurisdiction over some aspect of hydropower. A successful program must involve the cooperation of other agencies, special interest groups and licensees as well. State and Federal agencies must devise new processes of interagency coordination so that required considerations are expeditiously carried out in the public interest.

Licensees must recognize and accept the responsibilities and obligations of utilizing a public resource, availing themselves of agency staff expertise and entering into effective dialogue with special interest groups.

PANEL

Alex Radin, *Executive Director, American Public Power Association*
Leo Eisel, *Director, U.S. Water Resources Council*
Robert Smythe, *Sr. Staff, Council on Environmental Quality*
Lawrence F. Kramer, *Mayor, City of Paterson, N.J.*

PAPER SESSIONS

Public and private finance & policy issues — *recommendations, constraints and marketability*

Water: Management and use — *potential considerations, water rights, planning guidelines and policy recommendations.*

Environmental issues and impacts — *small scale impacts, DOE's program plan, land use consideration and legislation.*

Energy — *institutional, economic and environmental constraints, future alternatives, generation in rural areas and application to a utility system.*

International Perspectives

PLENARY

"I am devoted to hydropower. It is the most exciting professional subject . . . implementation of hydropower projects require the broadest application of several disciplines of engineering."

EMIL F. MOSONYI
Professor, Hydraulic Engineering
University of Karlsruhe
German Federal Republic

In the world, in many countries, not only the small-scale dam power plants, but also the typical low-head, run-of river stations located on low gradient streams will gain in importance.

In all stages of hydropower construction the process has been accelerated, particularly in the phases of foundation and tunneling works, machine assembly at site and prefabrication. Economic stimuli for water power utilization have been provided by advances in tunneling techniques. Examples of underground projects exist in Canada, Austria, Sweden, Norway, Italy and Switzerland.

Many river stretches and dam sites can be selected which have not been realized before as offering the chance for hydropower implementation. From the economically feasible potential of 4 million MW, only roughly 10% has been presently utilized.

Several aspects will contribute to a successful program in small-scale hydropower: true allocation of investment, realistic assumptions of equipment and structure lifetimes, up-to-date assessment of plant capacity, future contingency planning, feasibility study requirements in balance with economic and human values, midget plants that do not require sophisticated equipment, reduced planning and construction time, hydropower as an integral part of engineering education, and accelerated decision-making.

PANEL

Peter Bourne, *Assistant Secretary General, UN Water Decade*
Charles Weiss, *Science Advisor, World Bank*
Alan B. Jacobs, *Director, Energy Office, AID*
Francis X. Gannon, *Advisor to Secretary General, OAS*
Ricardo Saettone, *Director, Superior Vice Minister of Energy & Mines, Peru*

PAPER SESSIONS

Development experiences — *regulation comparison, non-oil producing nations, foreign aid for developing countries and development in the Peoples' Republic of China.*

Technology — *experience with small-scale turbines, appropriate technology and viable alternatives.*

V. WORKSHOPS

Eight workshops were held several times each during the conference. Each session lasted approximately 2 hours with a panel presentation followed by audience interaction.

The workshops and example topics with which they dealt were:

Finance and Marketing

Chairman: David Auslam, Auslam & Assoc.

Financing hydro projects, raising private backing, tax credits, investment bankers, marketing and calculating investment return.

Planning

Chairman: David Willer, Tudor Engineering

A feasibility study locating information and resources, designing, planning and implementing a project, converting into a utility grid, and wheeling power.

Developing Policy/Legal Context

Chairman: Peter Brown, Franklin Pierce Law Center

Identifying Federal, State, regional and municipal policies, government regulations, conflicting water uses.

Government Funding

Chairman: Ralph Burr, U.S. Dept. of Energy

Obtaining government funds, government programs.

Licensing

Chairman: Ronald Corso, Federal Energy Regulatory Commission

Applying optimal resource use, inspections, engineering and economic studies, preliminary permit, feasibility.

Engineering

Chairman: George Smith, U.S. Dept. of Energy

Assessing requirements, stream potential, power system, automatic vs. semi automatic.

Dam Inspection, Safety and Adequacy

Chairman: Robert Philleo, U.S. Army Corps of Engineers

Assessing a dam structure, matters and considerations to address.

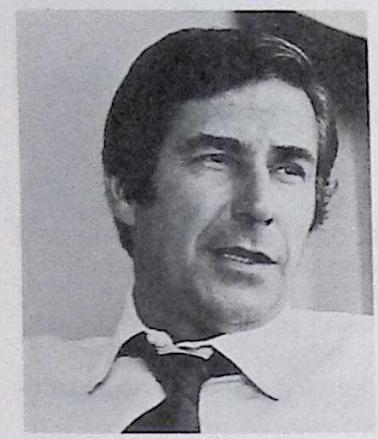
Environmental Issues

Chairman: Stephen Hildebrand, Oak Ridge National Lab

Issues affecting development, mitigation, issue solution, impacts, and regulations.

VI. SPECIAL PRESENTATION

Special addresses were given to the attendees of Waterpower '79 by members of the Congress and the World Energy Conference.



HON. MIKE GRAVEL
D-Alaska
U.S. Senate

The outlook for hydropower as an alternative energy source in the 1980's is integrally tied to the overall consideration and development of a comprehensive and effective national energy policy. To assess the future of hydropower in the next decade, it is necessary to understand and consider the current direction of this country's energy policies.

The development of hydroelectric power has always been subject to the market. Hydropower provided the foundation for the industrial development of this Nation and continued to grow until the regulation of natural gas took hold in the early 1960's.

In August Senator Mark Hatfield and Senator Gravel were joined by several other Senators in introducing Senate Bill 1641, the Small Hydroelectric Power Development Act of 1979. This bill will set up a continuing authority for the Corps of Engineers to site select, plan, design, and construct new low-head hydroelectric facilities. This authority is set up on a turn-key basis with the non-Federal entity owning and operating each facility and agreeing to pay back 100 percent of the Federal cost of construction plus interest over a fifty year period. Projects constructed under this act shall be limited to an installed capacity of twenty-five magawatts.

Most important, Senate Bill 1641 is designed specifically to provide small low-income communities with a source of renewable energy immune to rising oil prices. These projects will help provide such communities with a stable economic base for economic development in the 1980's.

SPECIAL PRESENTATION

HON. JOHN A. DURKIN
D-N.H.
U.S. Senate

In the state of New Hampshire it has been suggested that up to a third of the electrical power can be generated by retrofitting existing dams and taking advantage of some of the flood control dams.

Hydropower is currently very economical, but future costs of pursuing oil-based emergency energy resources, particularly in terms of military security, are equally important. By 1984 and perhaps sooner the Soviets will stop exporting one million bbls of oil per day to the West, they will become importers of oil and the pressure on the price and availability in the Middle East and elsewhere in the OPEC countries is going to be tremendous.

There are several things we must work on; make money available for loan guarantees; increase the investment tax credit for the businessman and the entrepreneur; set equitable power rates in the utility section; provide incentives to power generated from small-scale hydro and other small alternative energy sources; assist municipalities through loan guarantees.

We must use energy efficiently, otherwise we're not going to preserve economic standards and be independent.

The states can do a lot to help. The closer the spending of the money is to the taxpayer, the more efficient the distribution and utilization of the money.

"We are the most efficient in the world, but also the most energy intensive in the world. . . . inflation is hitting the necessities and it's primarily energy induced. We are never going to get it under control in my area of the country until we solve the energy problem. Hydro has a tremendous potential."

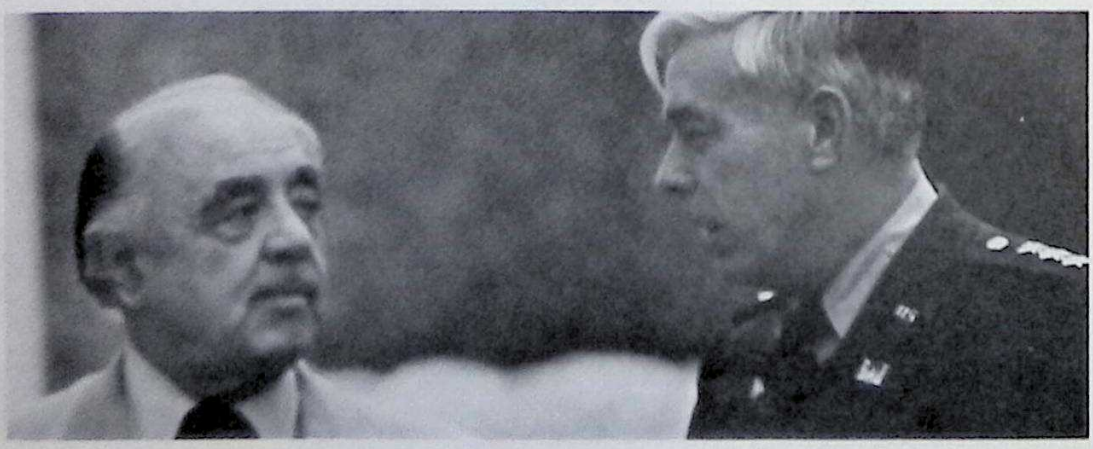
SPECIAL PRESENTATION

ELLIS L. ARMSTRONG
Chairman, Hydraulic Resources Division
World Energy Conference Commission on Energy Conservation
(Former Chairman, U.S. National Committee of The World Energy Conference)

The potential of developing small-scale hydropower is promising, but as with most things, there is no magic. Accomplishment takes work and effort and time. The challenges for development to occur become more difficult and more widespread as we have more people. And this is a fact that no fantasy or wistful thinking is going to change; more and more and more people are coming down the road.

The World Energy Conference Conservation Commission study concluded that the worldwide hydropower installations will increase about five times by 2020. It is expected the present 60,000 MW will be about double in the United States.

The challenge is for all of us to more realistically face up to the fundamental problems of mankind in order to meet the needs of the growing numbers of people in our world. Meeting the needs of people, both in the developed and the undeveloping countries, basically involves energy, water, and food; interrelationships are varied and complex. For instance, in the more affluent countries where food supplies seem assured, at least for the present, the emphasis is directed toward a fuller life, including increased services and cultural activity in an unpolluted quality environment. This requires greater energy from cleaner sources, and better management and control of water. In the developing countries, the emphasis is on adequate food, goods and services that reduce risks to life, and improve human conditions so that life is less arduous and more worthwhile. Worldwide, all are striving toward individual betterment, justice, harmony, and peace; these goals require economic growth and improvement, and this requires increased use of energy and better and increased utilization of water.



VII. WHERE DO WE GO FROM HERE

1. Results from current studies by the Corps of Engineers, Water and Power Resources Services, New England River Basin Commission and others will soon determine the feasibility and potential of hydropower and additional demonstrations funded by DOE will exhibit innovation, test equipment and prove economic viability. These results will lead the way for viable programs for both large and small-scale development.

2. Legislation is continuing to be developed which will assist in streamlining government agency procedures and providing technical assistance and incentives to private and public developers.

3. The attention of decision-makers must continue to be kept on the viability of small- scale renewable energy resources such as hydropower and efforts to refine and innovate the technology must go forward.

4. In order to maintain the momentum for international information exchange in hydropower, Waterpower '81 is being planned.

Date: June 22-24, 1981
Location: Shoreham Hotel, Washington, D.C.
Program: Plenaries, Papers, Workshops, Exhibits, Special Events
Sponsor: Corps of Engineers and other organizations interested in co-sponsoring or cooperative assistance

For more information, contact:

Waterpower '81
2033 M Street, N.W.
Suite 300
Washington, D.C. 20036

REPRESENTATION AT WATERPOWER '79

States — 46

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Mississippi
Missouri
Montana
Nebraska
Nevada
New Hampshire
New Jersey
New York
North Carolina
Ohio
Oklahoma
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Rhode Island
South Carolina
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WATERPOWER'79

an international conference on small-scale hydropower

OCTOBER 1-3, 1979

ABSTRACTS

U.S. ARMY CORPS OF ENGINEERS

U.S. DEPARTMENT OF ENERGY

WATERPOWER '79:

The First International Conference on Small-Scale Hydropower

ABSTRACTS

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

This publication contains abstracts of the papers presented at Waterpower '79. The views represented here are not necessarily those of the U.S. Army Corps of Engineers, the U.S. Department of Energy, or other public and private entities with which the authors are associated.

FOREWORD

Waterpower '79, an international conference on Small-Scale Hydropower held in Washington, D.C. on October 1–3, 1979, was cosponsored and funded by the U.S. Army Corps of Engineers and the U.S. Department of Energy.

The purpose of the Conference was to take advantage of timely subjects of appropriate technology and renewable energy sources by providing a means for information and exchange between local, state and Federal Government agencies, public and private utilities, research organizations, private consultants, equipment manufacturers, colleges and universities, the media, Congress, special interest groups, and the public at large.

Twenty-three technical paper sessions were held in which 89 papers were delivered, 4 plenary session presentations with panel discussion were held, 8 workshops were provided on a repeated basis, and special addresses were made by the White House, Congress, and other key participants. In all, over 1,200 people attended, over 200 of whom had a significant participatory role.

The intent of this publication is to provide the reader with some idea of the range of topics covered in the technical sessions, the author's background and a brief overview of the subject treated in each paper.

Waterpower '79: Abstracts was compiled and edited at the Institute for Water Resources. Those contributing were: Dr. David Zoellner, Chairman, Technical Program Committee Waterpower '79, and Technical Monitor for Waterpower '79 publications; June Fratus, editor, and Darrell Nolton, Technical Program Committee member, and special assistant, and Dr. Margaret Lambie, Department of Energy Project Manager for Waterpower '79.

A copy of this Publication will be sent to each Conference registrant and copies of the Paper Proceedings will be made available at a later date.

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Engineering Sessions

Session One

ENGINEERING

Topic: Equipment

Chairman: George Smith
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SMALL HYDRO CONTROL AND OPERATION

Howard A. Mayo, Jr.

During the last twenty years there have been several small-hydro installations with simplified automatic control systems. Induction generators permit the simplest and lowest cost control systems, therefore their characteristics and system impact become important.

Specific projects illustrate how control objectives can be accomplished to meet environmental objectives as well as water supply requirements. Starting sequences define the procedures followed and the adverse conditions which would cause shutdown.

Synchronous generators have a much broader field of application and are much more suited to the larger generating installations. Such units are no longer synchronized in the conventional sense as is illustrated by specific jobs in the Midwest and New England. Many installations may be controlled by headwater elevation or remotely to meet specific power production requirements. Speed governors may only be required when the turbine and generator are disconnected from a system or are to be used for "black start" purposes.

Because of its effect on the various control options and water control equipment timing, water hammer impact must be considered at an early stage of hydroelectric equipment selection. Propeller runners characteristically have high runaway speeds and the turbine discharge tends to increase with overspeed. Such characteristics must be considered in planning system controls.

Modern standardized hydroelectric generating units include standardized control systems which provide basic equipment protection as well as indications of abnormal conditions. The use of brushless exciters does, however, require some modifications from what might otherwise be considered conventional control systems. The challenge today is to provide a lower cost, therefore simplified and standardized control system, acceptable to both the powerplant developer and any system to which the power may be supplied.

ABOUT THE AUTHOR: Mr. Mayo received the B.S. degree from Worcester Polytechnic Institute, Worcester, Massachusetts. At the Allis-Chalmers Hydro-Turbine Division, York, Pennsylvania, he is responsible for market development for the Standard Products and Customer Service Department which includes water control products such as Bascule gates and Howell-Bunger valves in addition to small hydroelectric units and standardized hydroelectric units. Mr. Mayo has been largely responsible for the development and promotion of the TUBE turbine unit and its sale in North America. He holds several U.S. and foreign patents relating to hydraulic machinery, has presented numerous technical papers and has contributed to several text books on the subject of hydraulic machinery.

DEVELOPMENT CONCEPT FOR KAPLAN-TUBE-TURBINES

Otto Hartmann

The paper presents a novel arrangement of an axil-flow Kaplan turbine. The characteristic feature is the fixation of the runner blades in the rotating runner tube, not in the center hub as usual. Also the blade-positioning mechanism is arranged on the outside of the runner tube.

In addition to mechanical and hydraulic advantages this results in new possibilities of the general lay-out that allow simplification of the civil engineering structure and of the erection. Improved accessability for maintenance and repair and the use of high-speed off-the-shelf generators for small-capacity units are other possible benefits.

The proposed arrangement contributes to the development of tube-type turbines in general and more specific to the implementation of low-cost, low-head and small-capacity hydropower of high reliability and maintainability.

ABOUT THE AUTHOR: Mr. Hartmann received the M.S. degree in Mechanical Engineering from the Polytechnical Institute in Vienna, Austria. As Vice President, Motor-Columbus Consulting Engineers Inc., Baden, Switzerland, he is responsible for corporate technical development, after a long career in hydropower and related fields of power engineering.

SMALL-SCALE HYDRO: THE USE OF PUMPS AS TURBINES

John D. Lawrence

It is common practice in industrial applications for propeller or centrifugal pumps to be operated in reverse as turbines for power recovery purposes. Pumping equipment would appear to be much more readily available at short notice and relatively low cost than the equivalent turbine. The utilization of standard pumping equipment in small-scale hydro installations would present an ideal opportunity for cost reduction. Equipment would be selected from an inventory of available unit design which best fits the situation of maximized benefits or minimum cost.

Reduction of cost can also be achieved by such measures as the elimination of automatic shutdown facilities, taking full advantage of built-in overspeed capacity of machines, failsafe design approaches to gates and racks and the use of induction generators. The exclusion of adjustable wicket gates and blades on small propeller-type turbines can be economically justified by restricting the operation of a plant to a narrow head range with automatic flow-closure gates. Regulation of such small units connected to a large and stable system is also an unnecessary luxury.

The manufacture of complete "off-the-shelf" equipment packages would not only contribute to reduced production costs but also offer utilities the additional cost-saving potential of accelerated installation schedules. There are indications that cost savings of as much as $200 to $300 per kW of installed capacity (1979 price levels) could be achieved. Lowered energy costs for a typical peaking installation, would be equivalent to 1 to 2 cents per kWh.

Recognized turbine manufacturers have already initiated the production of packaged units. The Federal Government has also played a part in stimulating this interest. There is evidence that public and private utilities are keenly aware of the improving economics of small hydroelectric developments.

The purpose of this paper is to re-examine several promising new concepts in the design of hydroelectric generating equipment with a view to accelerating the economic construction of small hydro developments. The concepts to be studied will also be conducive to expansion of the available small turbine manufacturing capability in the United States. This in itself is likely to lead to reductions in equipment costs.

ABOUT THE AUTHOR: Mr. Lawrence received the B.Sc. degree from the University of London, England, and the M.Sc. degree from the University of Birmingham, England. Mr. Lawrence has more than 20 years experience in all aspects of hydropower engineering in North America, South America and Asia, and is a registered professional engineer in New York State, and is Project Manager, Acres American, Inc., Buffalo, New York.

MODERNIZATION OF HYDROELECTRIC UNITS

Grover F. Wachter

The present energy crisis has demanded solutions to overcome the ever-increasing costs of power generation and eventual depletion of the vast sources of our natural resources.

One of the natural resources which has been used to harness power is water. The early hydraulic generating units were of small size and their output seldom exceeded several hundred horsepower. While turbine units were generally considered successful in their day, today there are many existing hydro stations operating below their potential capacity. Full utilization of these hydro stations will derive maximum benefits from our natural water resources. Abandoned hydrogenerating units considered uneconomical for rehabilitation or modernization for the last twenty years are also being studied to utilize the excess water resources.

Improvements have also been accomplished with major electrical generating units in many hydro installations. The most common modification results in the replacement of the stator winding and the use of the existing rotor winding and exciter.

Modernization of existing hydroelectric units requires careful studies by xperienced hydraulic turbine and generator designers. In planning for any ıch modernization program, it is important to initially begin with studies f the existing hydraulic turbine to determine its capability for increasing apacity or efficiency.

Due to continued escalating costs of new generating units, scarcity and high price of clean fuels and strong resistance from environmental groups to modify the original terrain, upgrading of existing units has become increasingly attractive to powerplant owners.

Although the contribution to our Nation's increased energy requirements from modernization of existing hydrogenerating units may be a small percentage, it certainly is a step in the right direction.

ABOUT THE AUTHOR: Mr. Wachter received a B.S. in Mechanical Engineering from Pennsylvania State University in 1952. At Allis-Chalmers Corporation, he is responsible for the management of all activities of the Hydro-Turbine Division relating to work on existing hydro equipment. In addition, he supervises the staff of the Customer Service Department which is responsible for contracts on repair and replacement parts, engineering studies of replacement turbine runners, coordination of engineering studies and field tests, and other work relating to existing equipment. Allis-Chalmers Corporation is located at York, Pennsylvania.

THE OSSBERGER CROSS-FLOW TURBINE

F. W. E. Stapenhorst

The cross-flow turbine was invented by Mr. Michell in Australia at the turn of the century. A Hungarian engineer, Professor Banki, was responsible for its early development and popularity when the Ossberger Turbine Company in Weissenburg, West Germany, acquired manufacturing rights.

Over the years Ossberger, concentrating on small-scale hydro only, perfected the cross-flow turbine to today's high standards. The turbine has two moving parts, the guide vane and the runner. The guide vane controls the water flow and the design of the runner permits the water to pass through its blades twice.

When greatly varying water flows exist, the guide vane is divided, generally in a proportion of 1:2. This means that at low flow, only the small section of the guide vane is opened. With medium flow the 2/3 section is opened, whereas with full flow both sections are opened. This assures an efficiency of 83–84% at all gate openings, down to about 25%, and at 16% gate opening efficiency is still 75–80%. In addition, the turbine will accommodate fluctuations in head of about ±20%.

The generating sets are furnished with standard governor, speed increaser and generator for synchronous or induction generation. The turbine is available completely assembled, mounted on a frame, ready to be bolted to the floor. There are no imbedded parts.

The costs of civil works are relatively low. Service and maintenance are minimal. Many stations operate unattended and fully automatically. The turbines are of modular design, which reflects in price and delivery.

ABOUT THE AUTHOR: Mr. Stapenhorst is President of F. W. E. Stapenhorst, Inc., of Montreal, the distributor of Ossberger Cross-Flow Turbines for the U.S. and Canada. He is also the President of Tyton Seal, Inc., which manufactures mechanical seals, including large seals for hydraulic turbines. A Montreal resident for 30 years, his activities are centered in the U.S.A. and Canada.

Mr. Stapenhorst was educated in Germany, where he received the equivalent of a B.Sc. degree. During World War II he was co-responsible for the development in England of a temporary runway widely used by the Allied Air Forces, and shared in the receipt of a British Government award for these efforts.

Session Two

ENGINEERING

Topic: Redevelopment I

Chairman: J. Gavin Warnock
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REDEVELOPMENT OF OLDER HYDROELECTRIC GENERATING UNITS: A PLANNED APPROACH

A. G. Trott

There are approximately 500 old and generally low-capacity hydro-developments in the United States. Many are not operating and some of these have been transferred to municipalities for recreational facilities; particularly those having large reservoirs.

Small multiple, inefficient hydro-generation units are generally the rule and the costs of maintaining the structures as well as the difficulty of replacing the equipment has prompted many utilities to try and abandon these expensive plants.

Careful study will reveal that there are many of these old hydro plants that can be upgraded because they are still sound structurally; existing bays are large because the old initial equipment was large in size and it is this fact that will make it possible to upgrade these old plants with modern equipment.

Manufacturers of hydraulic turbines have devised highly efficient and compact units that include short penstocks with the turbine within, and the turbine shaft geared to a small high-speed generator. This type of unit is comparatively easy to install.

Governmental agencies favor these redevelopments and in some cases money is (forthcoming) available for initial and final engineering for these installations.

Renewal of licenses, if lapsed, should not present too many problems. Environmental impact reports, although required, will be minimal; it must be understood that governmental agencies are encouraging these redevelopments.

Run-off and stream-flow records that have been maintained during the operation of the old plants will be a more accurate guide for the installation of the new units than the design data originally conceived for the old plants.

Utilities are interested as established by contacts to redevelop their old plants providing that such redevelopment is feasible.

An overall plan is presented illustrating a two-phase approach for upgrading existing hydro-electric generating units, while minimizing cost exposure.

ABOUT THE AUTHOR: Mr. Trott received the B.S. degree in Civil Engineering from Northwestern University. In previous association with a leading engineering and design firm he was responsible for directing project engineering work relating to the design of hydro-electric generating projects and underground municipal water pumping stations. Mr. Trott is Senior Marketing Representative, Power Design Services, Inc., Glen Ellyn, Illinois, and presently responsible for marketing and project planning work for redevelopment of small hydroelectric generation units.

SMALL-SCALE HYDROELECTRIC DEVELOPMENT AT EXISTING PUBLIC PROJECTS

Daniel E. Steiner and Albert R. Stritt

About 80 Federally-developed, multiple-purpose reservoirs and navigation dams within the Ohio River Basin exhibit small-scale hydro potential. Formulation of economically viable and socially acceptable plans for development of this small-scale hydro potential presents an opportunity for innovative design and operational concepts and public involvement activities which are applicable to many other public and private projects.

Hydraulic conveyance facilities can comprise a significant component of the costs of developing hydro facilities at existing dams. Economic feasibility of hydro installations (particularly smaller installations) may depend upon developing a cost-effective concept for incorporating hydraulic conveyance facilities into existing project features. Development of the most cost-effective conveyance concept requires site specific studies by a planning/design team and consideration of all applicable conveyance techniques. If a feasible concept for hydraulic conveyance facilities cannot be developed for the most desirable level of hydro potential, a lesser hydro capacity which is compatible with available conveyance facilities should be evaluated.

Current project operations generally reflect a balance among conflicting demands. Optimum development of hydroelectric power suggests storage reallocations and operational modifications which could disrupt this existing balance. Reasonable trade-offs can be identified at most existing projects. Seasonal peaks in demand for electric power are a particularly promising opportunity for such trade-offs.

Most existing Federal projects were developed for the purposes of flood control, some form of water supply and/or commercial navigation. However, recreation use is the general public's predominant contact with these projects. Public understanding and perception of an overall increase in beneficial project services is an essential prerequisite for public acceptance of plans for the addition of hydro to existing projects.

ABOUT THE AUTHORS: Mr. Steiner received the B.S.C.E. from Ohio University and is a registered P.E. in the State of Ohio. He currently has program responsibility for hydroelectric power, flood control and multiple purpose planning studies in the Ohio River Basin, U.S. Corps of Engineers, Ohio River Division, Cincinnati, Ohio.

Mr. Stritt received the B.S.A.E. from the University of Georgia and is a registered P.E. in the State of Florida. In addition, Mr. Stritt has experience in hydropower planning for the Arkansas River Project and for rivers in Puerto Rico. He is Project Manager, Plan Formulation Br., U.S. Army Corps of Engineers, Ohio River Division, Cincinnati, Ohio.

POLICY FOR APPLYING SMALL HYDRO TO A UTILITY SYSTEM

Arthur E. Allen

For the National economic welfare it is essential that the utmost benefit be obtained from all energy that is produced. Therefore, hydro plants, large or small, should be analyzed relative to the electric utility system in their area.

The United States power system is composed of approximately 500,000 MW of thermal generation and 72,000 MW of hydro generation including pumped-storage. Load factors in the U.S. are relatively high with national annual load factors about 61%.

In most of the United States there are not sufficient hydoelectric resources available to take care of all the load above the base load. The result is that there is a mix of high-temperature, high-pressure steam units for base load, lower temperature, low-pressure steam units for the intermediate loads, and combustion turbines for the peak loads.

Where hydro plants are present they should be utilized to replace less efficient thermal, oil or gas-fired generation and provide as much capacity as possible at time of peak loads. The constraints on effective hydro utilization are (1) the amount of storage available for seasonal, daily or weekly flow regulation, (2) the extent to which turbine discharge can be varied hourly or daily, and (3) the existence and characteristics of reregulating hydroelectric plants. The amount of storage is affected by prior commitments, e.g., flood control, low-flow augmentation and recreation. Turbine discharge fluctuations impact on downstream recreation, wildlife and shoreline aesthetics and these aspects must be studied and compared to natural conditions so that hydro is not restricted unnecessarily.

Preliminary results of a current study for a hydroelectric plant in a power system with a high system load factor are presented. The principles discussed herein are being applied in the studies.

ABOUT THE AUTHOR: Mr. Allen received the B.S. and M.S. degree from Carnegie Institute of Technology in 1938 and 1939, respectively. He has a total of 38 years experience with the U.S. Army Corps of Engineers, and the Aluminum Co of America. At Harza Engineering Company, Chicago, Illinois, he is the Vice President and Chief Power Development Engineer, and presently involved in studies for surface and underground pumped-storage projects, conventional hydro and compressed air energy storage. He is a Fellow in the ASCE and has served on ASCE committees and panels in the Power Division.

HYDROPOWER DEVELOPMENT AT WATER SUPPLY DAMS

Lewis E. Linzell

Dams constructed for municipal water supply impoundment are one of the most common types of existing dams in the Midwest and therefore, attractive candidates for small-scale hydropower development. These dams have several inherent features which are favorable to feasibility. The impounded reservoirs are maintained at the maximum possible elevation and the power produced can often be used by the nearby water treatment plant, simplifying transmission and allowing the power producer to be the user as well. For municipalities, an additional advantage is that municipally-owned water utilities can obtain favorable interest rates. Because of the capital intensive nature of hydropower development, this is a factor of major importance.

While water supply storage cannot be drawn down for power production, hourly variations in releases can be allowed in order to maximize the peaking output of power. This can be carried out by utilizing acceptable fluctuations in reservoir levels, on the order of a few inches in some cases. Such operations can substantially increase the per kilowatt hour value of power produced.

These sites do have some inherent disadvantages. Water cannot be wasted from storage for power generation. In some cases the raw water is transmitted to the treatment plant by a closed conduit from the reservoir, complicating and generally adversely affecting hydropower feasibility. Raw water quality requirements may dictate having a variable reservoir outlet capability, which may place additional restraints on operation and complicate design. Also, many of these reservoirs are used for recreation as well as water supply; this use must be considered concurrently with the other two.

The effect of the above-noted items and other features upon the feasibility of hydropower development will be discussed in relation to several municipal water supply dams which have been investigated by the author. Approaches which take maximum advantage of the site characteristics will be emphasized, and appropriate means of dealing with use conflicts noted.

ABOUT THE AUTHOR: Mr. Linzell received the B.C.E. from the Ohio State University and the M.C.E. from Yale University. At Burgess and Niple Limited, Columbus, Ohio, he is a Project Engineer in the Bridge and Structural Section involved in hydroelectric feasibility studies, design of and repairs to dams, inspection of dams and hydroelectric plants, and the design and inspection of other structures.

Session Three

ENGINEERING

Topic: Generation Systems

Chairman: William E. Rumberger
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ENERGY LOSSES AT HYDROELECTRIC POWERPLANTS

C. C. Purdy

An indepth analysis of the energy losses at existing hydroelectric plants should be made in order to identify and assess the magnitude of each separate energy loss. An estimate should then be made of the reduction possible in each loss. The implementation of corrective action will then improve the generating capacity of existing plants. Costs of operation and maintenance should also be analyzed and categorized as to possible benefits. The criteria developed for existing plants can then be used as design criteria for new hydroelectric plants.

This paper deals with some possible practical improvements in the efficiency of hydroelectric generating plants, based on identification, magnitude, and reduction of energy losses. Turbine runner efficiency has nearly reached its peak. Reversing the trend to use higher specific speeds, reduction of draft tube exit loss and the use of different size units are discussed.

ABOUT THE AUTHOR: Mr. Purdy received the B.Sc. (Mechanical Engineering) degree at the University of Saskatchewan in Canada. At TAMS he is responsible for design of the mechanical elements of hydroelectric power plants, pumping stations and feasibility studies. His 35 years professional experience covers most aspects of turbines, pumps and plant design. Tippets-Abbett-McCarthy-Stratton is located at 655 Third Avenue, New York, New York.

A REVIEW OF INDUCTION GENERATORS AND THEIR APPLIÇATION TO SMALL HYDROELECTRIC POWERPLANTS

John Slapp and Narain G. Hingorani

Throughout the world there are literally millions of small rivers and streams which are not being used to generate electrical energy because they have low or erratic flow. The object of this paper is to show that these water sources could be used to generate electrical energy by employing induction generators.

This paper will review the theory of induction machines and their past application as a generator. It will show that the induction generator is ideally suited to small hydroelectric plants since it does not require an excitation or governor system and is robust and simple in construction. The induction generator requirement for reactive power from the system will also be discussed, as well as the merits of compensating for it, if required, by using automatically switched or thyristor controlled capacitors.

The paper will show that the induction generator, when connected to a simple back-to-back converter system, can be used to generate power into a 60 Hz system, at both subsynchronous and hyposynchronous speeds. This wide speed range, with the simplicity of the machine and the commercially available converter systems, which can be used for DC transmission for remote hydro sites, will allow even minor streams to be used as hydroelectric sources.

ABOUT THE AUTHORS: Mr. Slapp is a licensed professional engineer in the States of California and Illinois and has 25 years experience in power system design and rotating plant. He is currently Assistant Project Director-Engineering, for the Inga-Shaba 500 kV EHVDC Transmission System, Zaire, Africa, and Project Manager for the Electric Power Research Institute (EPRI) State of the Art Study on Grounding Electrodes. He has been involved in DC transmission for the last 10 years.

Dr. Hingorani joined the Bonneville Power Administration in 1968 and was responsible for commissioning the Pacific HVDC Intertie, design of series capacitor protection, and coordination of systems engineering for the 1,000 kV Prototype Transmission Line. In 1974, he joined the Electric Power Research Institute as Program Manager for AC and DC Transmission. In this capacity, he is fully aware of the most advanced technology available and under development. Dr. Hingorani is co-author of a book on HVDC transmission and author of over 70 papers. EPRI is located at Palo Alto, California.

CALCULATIONS OF CIRCUIT BREAKER CLOSING CRITERIA FOR SYNCHRONIZING A GENERATOR

Robert W. Beckwith

Severe damage can be done to a hydro generator by improper synchronization. Modern automatic synchronizers eliminate this danger. Simple formulae for phase-angle accuracy and maximum allowable frequency difference at the instant of closing a generator breaker to tie it to a power network are given below.

CALCULATION OF AUTOMATIC SYNCHRONIZER SETTINGS:

Data Required:

H the machine inertial constant in seconds.
$\underline{x}_t$ the sum of the machine transient impedance, transformer impedance and line impedance in per unit.
t_f the expected fault clearing time at the generator in seconds.

Procedure:

Calculate: $D_t = t_f / H$, a dimensionless per unit number related to a fault transient.

Choose a safe D_f less than D_t related to the synchronizing transient.

Calculate: $\Delta f_s = 30 D_s$, maximum allowable slip rate in Hertz.

Calculate: $\delta_s^\circ = 787 D_s$ less $\left(H \underline{x}_t\right)^{1/2}$, maximum allowable closing angle error in degrees.

The fundamental resonant frequency of the generator and interconnected system is:

$$\alpha' = 2.185 \left(\frac{1}{H \underline{x}_t}\right)^{1/2} \text{ resonant frequency in Hertz.}$$

ABOUT THE AUTHOR: Mr. Beckwith received the B.S.E.E. degree from Case Western Reserve and M.E.E. degree from Syracuse University. He is a Fellow of the Institute of Electrical and Electronics Engineers. After 21 years with General Electric as supervisor of Power Line Carrier Development and Manager of Computers in the Electronics Laboratory, he founded Beckwith Electric Co., Largo, Florida in 1967.

THE STANDARDIZED MINI-HYDROPOWER STATION

Johan Bergseng, Hermann J. Besel, Friedrich Riezinger, and Horst Butz

Electrical Parts:

a) The Generator

The paper discusses the criteria which govern the selection of generator type (synchronous or asynchronous) during the project planning of Mini Hydropower stations. These criteria may be hydraulic characteristics such as runaway speed or moment of inertia, or operating requirements such as parallel or isolated-made (islanding) operation under constant or variable load. Accordingly, the characteristics of synchronous and asynchronous generators are compared and recommendations for their application are made.

b) Switchgear and Control System

A standardized protection system is used, chosen according to generator type and rated voltage.

To ensure the safety of an unmanned power station, special consideration is given to temperature monitoring of the bearings and the stator.

The use of an automatic run-up and shutdown system provides for single operation of the plant.

The starting procedure for asynchronous generators is demonstrated by means of oscillograms. The fully automatic and voltageregulated excitation system for synchronous generators is described. The behavior of asynchronous generators during voltage fluctuations in the grid and also the switching of the power station into the public grid are discussed.

c) Modernization of Existing Hydropower Stations

Renewal and uprating of existing Small-Scaled Hydropower Stations is getting more and more attractive in the future.

It is shown by an example how investigations have to be carried out in order to get the best result on technical and economical aspects.

ABOUT THE AUTHORS: Mr. Bergseng is Sales Manager, A/S Norsk Elektrisk Brown Boveri, Division Engineering, P.O. Box 429, Oslo 1, Norway; Mr. Besel is Section Manager, BBC Brown Boveri Company Ltd., Sales and Contract Dept. for Hydropower Plants, 5401 Baden, Switzerland; Mr. Riezinger is Section Manager Deputy, BBC Brown Boveri Company Ltd., Engineering for Hydrogenerators, 5242 Birn, Switzerland; and Mr. Butz is Product Manager for Mini Hydropower Plants, Brown Boveri Corporation, 1460 Livingston Ave., North Brunswick, New Jersey.

Session Four

ENGINEERING

Topic: Hydraulics and Hydrology

Chairman: Vernon Hagen
Engineering Division
U.S. Army Corps of Engineers
Washington, D.C. 20314

HYDROLOGY FOR HYDROPLANT PLANNING AND DESIGN

John H. Dixon

Development, understanding and application of hydrologic data are essential elements in the planning and design of hydroelectric plants. The hydrologic input to the design consists mainly of developing stream flow records and headwater and tailwater levels for estimating the power capabilities of a site, and flood frequency data for powerhouse design. Hydrologic procedures for this work have evolved over the years. Recent trends have been to use the electronic computer to process the large amount of stream flow data that is now available.

This paper recounts some recent experiences gained in the application of hydrology to studies and designs for power developments in the Northeast. This includes general procedures such as the development of a generalized flow duration curve applicable to New England that can be used for site screening, and obtaining and processing of daily stream-flow data for power estimates at specific sites. Comparison of power estimates developed from flow duration curves and actual daily flow records are made.

ABOUT THE AUTHOR: Mr. Dixon received a B.S. degree from the University of Florida. At Tippetts-Abbett-McCarthy-Stratton, New York, N.Y., he has been the project engineer for the feasibility design of two small-scale hydroelectric projects in New York, and one each in Vermont, West Virginia and Louisiana. He has extensive experience in the development of water resources projects.

DETERMINATION OF DURATION CURVES AT UNGAGED POINTS IN REGULATED STREAMS

Rickey Emmert and Leroy F. Heitz

An important aspect of determining the feasibility of a proposed small hydroelectric installation is determining the variability of streamflow. In many cases a duration curve technique is used to describe this time variability of flow. Developing a duration curve at some sites can be a problem if there are no nearby streamflow gages. A team of Northwest University researchers has developed techniques for determining duration curves in natural unregulated streamflow regimes. These methods have been published in other sources.

It is the purpose of this paper to discuss methods that have been developed to define duration curves along streams where the flows are regulated by upstream storage, by irrigation diversions, or by other types of depletions.

The method uses known streamflow records as starting points. Using the method one can move upstream or downstream from the starting point to determine a duration curve at some desired location. Tributary inflow above or below the starting point is determined using the average runoff from the tributary area distributed in the time domain based on the pattern of some previously chosen representative gaged flow. Average runoff is determined using normal annual precipitation maps.

The technique has been developed to the point where large tributary rivers with varying runoff factors, and varying mixes of regulated and unregulated tributaries can be handled fairly easily. The technique has been tested on several basins in Idaho with very good results. The methods used are straightforward and readily adaptable to computer techniques.

ABOUT THE AUTHORS: Mr. Emmert received the B.S. degree in Mathematics from Boise State University in Idaho and the M.S. degree in Civil Engineering from the University of Idaho. Mr. Emmert's M.S. thesis was involved with development of duration curves for both natural and regulated streams. He is a hydraulic engineer, Walla Walla District, U.S. Army Corps of Engineers, Walla Walla, Washington.

Mr. Heitz obtained the B.S. and M.S. degrees in Civil Engineering from the University of Idaho and is presently a Ph.D. candidate at that Institution. He is presently Project Coordinator for the Pacific Northwest Region Small Hydro Survey being conducted by the University of Idaho for the Department of Energy. In the past Mr. Heitz has worked for the U.S. Army Corps of Engineers and Tudor Engineering Co. in the fields of Water Resource Planning and Hydrology.

COMPLEXITY OF HYDRAULIC PROBLEMS IN LOW-HEAD HYDROELECTRIC DEVELOPMENTS

Alexander B. Rudavsky and Sun-Quan Yuan

One would assume that the hydraulic design problems and solutions for high dams would be more complex and difficult than low-dam developments, but just the opposite is true.

Due to the buffering effect of a large reservoir behind a high dam and the dependence between headwater and tailwater levels, the hydraulic analysis is relatively simple. However, in the case of low-dams, complex, ever-changing flow conditions are generated which can be analyzed only by engineers with considerable hydraulic expertise. The flows over low-dam structures are directly responsive to the dynamics of the water course. In addition, all problems inherent in the river conveyance, such as sediment transport, extreme flood fluctuations, and icing problems, become quite pronounced and possibly aggravated in low-dam developments.

The paper will discuss the complexities of the layout of river dams, spillway hydraulics, gate regulations, and energy dissipation. Problems of gate vibrations, sediment transport, icing, and debris will also be discussed and some solutions will be explored. The paper, based on 25 years of experience in modeling low-dam structures, will be illustrated and many design criteria will be expressed in terms of dimensionless analysis.

ABOUT THE AUTHORS: Dr. Rudavsky received a doctorate from the Franzius Institute Technical University of Hannover, Germany. He was a Freeman Scholar and studied at major European laboratories. He is a professor of Civil Engineering at San Jose State University in San Jose, California, and has served as visiting associate professor at Stanford University, Stanford, California. Dr. Rudavsky is the Founder and President of Hydro Research Science in Santa Clara, California. The firm is an applied research laboratory doing hydraulic modeling studies and serving domestic and foreign firms, public utilities and government agencies.

Mr. Yuan received the M.S. in Civil Engineering from the University of Pittsburgh and the M.E. from the University of California, Berkeley. He was awarded a research grant by the National Science Foundation and has published several papers including "Some Properties of a Second Order Hydrologic Model," "Parameter Estimation in a Second Order Runoff Model," and "Utilization of Model Studies in Pump Intake Design."

HYDROLOGIC INVESTIGATIONS FOR HYDROELECTRIC POWER

James G. Dalton and Gary M. Franc

This presentation summarizes the hydrologic investigation techniques and the computer-modeling techniques used in the U.S. Army Corps of Engineers National Hydroelectric Power Resources Study. An extensive, computer-oriented data base was conceived, designed, and implemented. Major considerations in designing the data base were that it be comprehensive, flexible, and relatively inexpensive.

A series of computational techniques and a five-step screening plan were established. These procedures were intended to accomplish data collection, analysis, and project selection within approximately 2 years.

The power potential and average annual energy computed at the point of maximum net benefits were selected for subsequent screening and were printed in our report *National Hydroelectric Power Resources Study—Preliminary Inventory of Hydropower Resources* for those projects with power potential greater than 500 kilowatts and a benefit-to-cost ratio greater than one. Of the approximately 17,000 sites investigated at this stage, 11,207 sites were summarized. These figures include approximately 2,000 projects with a potential greater than 1,000 kilowatts, which have been selected for advanced study.

After screening results from the advanced analyses of physical potential, additional environmental, political, and socioeconomic information on the remaining projects will be gathered to determine their effects on the potential hydropower development. This will essentially complete the National Hydropower Data Base. At that time, field level judgment will be required in selecting and ranking of projects for development within each Corps of Engineers district boundary.

ABOUT THE AUTHORS: Mr. Dalton is a member of the U.S. Army Corps of Engineers' management team for the National Hydroelectric Power Resources Study and has primary responsibility for the national inventory of data being gathered and analyzed for that study. Since 1965 he has worked on multi-purpose reservoir regulation plans and hydroelectric power studies for the Corps of Engineers in the Little Rock District Office and in the Southwestern Division Office in Dallas, Texas. Mr. Dalton is a registered professional engineer in the States of Arkansas and California and a member of ASCE.

Mr. Franc is a Hydraulic Engineer at the Hydrologic Engineering Center (HEC), in Davis, California. He has been developing the data management, editing, and analysis programs for the National Hydroelectric Power Resources Study. From February of 1976 to October of 1977, Mr. Franc worked as a Hydraulic Engineer at the Corps District Office in Buffalo, New York. Mr. Franc held the position of Assistant Hydrologic Engineer for the Power Authority of the State of New York (PASNY) from July 1973 to February 1976.

Session Twelve

ENGINEERING

Topic: New Ideas, Concepts and Technology I

Chairman: Richard McDonald
Institute for Water Resources
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RESEARCH AND DEVELOPMENT NEEDS FOR ALTERNATIVE APPROACHES TO SMALL HYDROPOWER

Edward J. Fritz

New ideas and hardware are needed in the interrelated areas of turbine control and energy conversion devices. This will give the hydro engineer and developer alternative ways to recover hydropower and may make some marginal sites economically feasible.

Conventional small hydroelectric powerplants compete with large central generation stations and large hydro at the very thing the big plants do best, namely, generation of high quality voltage and frequency regulated power. Complex governors and controls are required to maintain constant speed and reasonable efficiency while load, flow, and head vary. Especially when isolated operation is required, speed control becomes complex and expensive, helping to make hydropower recovery uneconomic at many small sites.

There is a potential market for alternative approaches to small hydropower where heat, and not electricity, is the desired end product. For example, at urban damsites the developer might want to directly generate hot water or steam for local district heating or greenhouse operation.

This will require development of turbines with simplified controls that do not need to operate at constant speed, and energy converters that make hot water or steam in a "hydrothermal" process, or make unregulated power that is expended in resistor banks in a tank of hot water. Either system can be integrated with other alternative energy sources since the water can be heated with solar, wind, or waste heat energy.

These approaches are only as good as the hardware and systems that are readily available to the designer. Systems should be available as "black boxes" that can be specified without benefit of an intimate knowledge of the theory of turbines and generators. At the present time, direct thermal conversion hardware and simple unregulated generators are available and are being applied to experimental wind turbines. Such systems will be developed for small hydro, and will become available at a reasonable price, only as a market develops.

These are areas where Federal R&D and demonstration grants could be utilized to help make alternative approaches to small hydropower recovery available to the designer and developer.

ABOUT THE AUTHOR: Mr. Fritz received the B.S. and M.S. degrees in Chemical Engineering from Rensselaer Polytechnic Institute and Lehigh University. He works for Polytech, Inc., Cleveland, Ohio, a consulting engineering firm, in the fields of design review and operation and maintenance of wastewater treatment plants. As an independent consultant, Mr. Fritz recently completed a hydropower feasibility study for a dam near Cleveland.

CONCEPTS FOR SMALL-SCALE HYBRID SOLAR-HYDROELECTRIC POWERPLANTS

R. Lewis French and K. Thomas Miller

A hybrid solar-hydroelectric powerplant is defined as a hydroelectric plant whose water resources and power output are enhanced by the use of solar-powered pumps to recycle a portion of the discharge water. Such plants have potential for enabling effective utilization of existing dam sites which otherwise may be unattractive for hydroelectric generation because of marginal or intermittent water resources. The hybrid approach provides an effective solution to the difficult energy storage problems encountered in producing and utilizing electricity from solar energy. Hybrid solar-hydroelectric powerplants appear particularly attractive for the southwestern regions of the United States because of the excellent solar availability and the limited water resources.

Several concepts for hybrid solar-hydroelectric powerplants have been formulated. The most direct approach employs solar photovoltaic arrays whose electrical output operates pumps for recycling discharge water. Current efforts to improve photovoltaic efficiency and reduce costs make this approach attractive for the long term.

Other concepts use solar collectors to heat a working fluid to high temperatures for driving heat engines coupled directly to the recycling pumps or, coupled to electrical generators whose output drives the pumps. The latter approach, along with the photovoltaic approach, has the advantage of not requiring that the solar arrays be in the immediate vicinity of the dam. The solar-generated electricity may be conditioned and fed into the distribution grid during periods when water resources are ample and recycling is not required.

Actual case studies of a detailed nature will be required to fully delineate the potential of hybrid solar-hydroelectric plants. Based upon preliminary studies, it is believed that further consideration of hybridization is merited.

ABOUT THE AUTHORS: Mr. French received the M.S. in Physics from Vanderbilt University. As a specialist in radiation physics, he spent over 15 years researching a wide variety of nuclear energy applications. Active in the solar energy field since 1974, he is presently Chief Scientist for the Fort Hood Solar Total Energy Project at American Technological University, Kileen, Texas, where he also teaches energy resources management.

Mr. Miller, who holds a B.S.degree in Aeronautical Engineering, has over 25 years of design and management experience in aeronautical, marine, powerplant, and hydroelectric systems. As President of Fluid Energy Systems, Inc., Los Angeles, California, he is responsible for the systems engineering, design, marketing and administration of hydroelectric generating programs.

THE SCHNEIDER ENGINE: PERFORMANCE AND APPLICATIONS FOR HYDROPOWER

Daniel J. Schneider and Emory K. Damstrom

The introduction will briefly assess the logic for design of low-velocity/low-head energy conversion systems. Commencing with a brief discussion of the physics and mathematics involved, mechanical choices, criteria for machine design, and finally the evolution of the Schneider Engine as a design of choice, this section sets out the physical advantages and disadvantages of lifting vs. drag and translating vs. rotating mechanical options. Both momentum-head (wind, ocean current, open stream) and pressure-head (confined—flow passageway) concepts are introduced.

The second part will briefly discuss a theoretical analysis and laboratory test results of confined-flow operation of the Schneider Engine. A theory based on fluid momentum was developed to provide design guidance and to predict the flow conditions and operating characteristics defined by non-dimensional coefficients unique for the Schneider Engine. Validity of the theory is confirmed by agreement with test data for a model tested at the University of California, Davis Hydraulics Laboratory. The test results indicate the Schneider Engine efficiency in excess of 80 percent.

The third part draws conclusions about the technological advantages that include large flow area at uniform velocity, avoidance of centrifugal force stresses, and avoidance of cavitation. Cost analysis shows the Schneider Engine to be very price competitive, costing as low as $700/kW water-to-wire at heads under 15 feet and costing about 50 percent of conventional turbines at heads between 15 and 50 feet. Finally, a river management scheme for power production is represented which offers approximately the same total power output as the Dickey-Lincoln School Lakes Project, but without inundation of valuable wilderness, agricultural, and inhabited land; a program that could be applied to almost any river.

ABOUT THE AUTHORS: Dr. Schneider received the M.D. from UCLA. He has investigated fluid energy conversion systems during the past 20 years and has conducted extensive research and development for fixed-location system operation.

Mr. Damstrom received the M.S. from SMU and has worked extensively in fluid mechanics applied to lift translator design. Dr. Schneider and Mr. Damstrom are with Schneider Lift Translator, Inc., Box 81, Justin, Texas.

SITE-BUILT, MILL-RACE COMPONENTS FOR SMALL-STREAM UTILIZATION

Timothy J. Maloney

The streams that powered mills prior to rural electrification have been largely abandoned as an energy source. The abundance of these streams offers rural communities a fall-back position in projected times of shortages. A drawback to development of old and new mill sites is the complexity of mill race layout, construction and maintenance.

Sample sites were studied to generate design parameters. A design was sought that would offer to rural communities reliable, low-cost, site-built, mill-race components. Criteria included ease of construction, errosion considerations, installation, maintenance, and modular flexibility. Parameters indicate a molded-in-place, modular concrete unit can be reliably installed by local contractors. Two types of modules will be described including: reusable mold module and an integral mold module. An adjustable interconnection detail provides the means for simplified layout. It will be shown how proper fall is provided by a calibrated adjuster built into the module.

ABOUT THE AUTHOR: Mr. Maloney received the M.F.A. degree from the University of Notre Dame, where he studied industrial design. He founded One Design, Inc., which has received various national awards for alternate energy utilization, including a waterwall module which is being used in many East Coast states for home heating. Integrating water power, solar power and biomass at the village level is the current thrust of One Design's work. He is President, One Design, Inc., Mountain Falls Route, Winchester, Virginia,.

Session Nineteen

ENGINEERING

Topic: Redevelopment II

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SMALL-SCALE HYDROPOWER APPLICATION OF HYDROELECTRIC "MINI UNITS"

H. Sattler

As a result of the continuous search and pressing need of alternative energies, small-scale hydroelectric power is widely discussed and applied throughout the world. This trend has prompted the development of modern type hydroelectric "mini units," and the concept has found widespread applications in sizes from a minimum of 50 kW to about 500 kW; while heads could vary from 1 m to 800 m. Site-specific conditions, nature of load and type of service determine its proper application. In developing countries or remote areas where infrastructure such as transmission facilities are not readily available, governor-controlled synchronous generator units meet best the wide variation in power demand for an isolated type load. Asychronous generator units are generally interconnected with an existing transmission system as it is usually available in more developed countries. Although the application of such generator units are limited in capacity up to a range of 2,000-3,000 kW this type of installation has the advantage of lower equipment cost and simplest operation.

Turbines need to be simply built for reliability, low cost, short delivery and easy assembly. To meet these requirements complete off-the-shelf package units have been developed and technical particulars of such standard designs are now readily obtainable from turbine manufacturers.

To cover the small-scale hydropower application range the following turbine types are available from the VOEST ALPINE-KOSSLER production program:

Pelton, Francis (compact spiral- and straight flow units), Kaplan, Tube and Reiffenstein turbines.

To bring down investment costs for plant and equipment and to shorten delivery time, the proper application of such hydroelectric "mini units" is discussed in this paper.

ABOUT THE AUTHOR: Mr. Sattler is Manager, Small Hydroelectric Power Plants, VOEST ALPINE AG, Finished Products Division, Hydro Power Plants Engineering Department, P.O. Box 2, 4010 Linz Austria.

DAM SAFETY—AN IMPORTANT FACTOR IN CONSIDERING SMALL-SCALE HYDROPOWER AT EXISTING RESERVOIRS

Anthony R. Dolcimascolo

An assessment of the safety of an existing dam may be as important a consideration in the evaluation of small-scale hydropower as are studies of hydrologic capacity, technical feasibility and economic viability. The Federal Energy Regulatory Commission, in protecting the public, requires that license applications contain enough information to show that the structures are safe. It is also in the best of interests of the applicant to protect his investment and, perhaps, limit his liability against potential disastrous results which could be caused by existing unsafe conditions.

The high potential for unsafe conditions at existing dams has been documented by the U.S. Army Corps of Engineers after the 1978 program of inspecting non-Federal dams in the United States in which nearly one-quarter of the dams inspected were found to be unsafe.

Safety inspections and field investigations needed to assess dam safety are best included at an early stage in the evaluation of hydropower potential. Combining these investigations with those needed for engineering of the powerplant would be economical and could lead to early recognition of potential problems which would have to be mitigated at some cost to the applicant in pursuit of a license.

As a general rule, the assessment of dam safety should consider such items as flood hydrology, spillway discharge capacity, stability of the dam and their effect on the powerplant installation. Special studies and field investigations may be necessary if problems and unsafe conditions have been identified during other inspections, particularly if the dam happens to be one of those found to be unsafe by the Corps.

ABOUT THE AUTHOR: Mr. Dolcimascolo, an Associate and Principal Engineer with Tippetts-Abbett-McCarthy-Stratton (TAMS) New York, N.Y., is a Civil Engineer specializing in the field of geotechnology. He currently directs dam inspection and rehabilitation programs for TAMS.

HYDROELECTRIC POWER GENERATION POTENTIAL AT RETIRED PLANT SITES

Eugene A. Jarecki and Daniel R. McConnell

Before 1979, about 75 percent of the small hydropower plants with a generating capacity under 15 megawatts were retired. Reasons for retirement were primarily economic while other reasons included abandonment due to obsolete or worn-out machinery, environmental and social impacts, dam breaching, or serious damage from flooding, reservoir inundation (due to new dam construction), change in legislation, change in use, and many other considerations.

These retired sites range in generating capacity of up to 11,000 kW. The approximately 1,900 retired plant sites had an individual generating capacity from 500 kW to 10,000 kW, with a total generating capacity of about 1,300,000 kW, many of which should be considered for redevelopment. Approximately 50 percent of these retired plants are located in the New England States. Out of the approximate 2,000 retired plant sites identified, about 45 percent are owned by utilities, about 45 percent are industrially owned, while the remainder are either owned by a municipality, a cooperative, the Federal Government or a private individual.

A retired plant list, compiled by FERC staff in the Division of River Basins, identifies retired hydroelectric sites to facilitate the redevelopment of promising sites. The list gives the plant name, owner, head where available, state, stream name, and the FERC river basin code which may be used to locate the stream. The list is continually updated.

ABOUT THE AUTHORS: Mr. Jarecki received the B.S. degree from the University of Nebraska. He worked with the Water and Power Resources Service (formerly Bureau of Reclamation) as a Hydrologic and Investigations Engineer, and with the Great Lakes Basin Commission as a Comprehensive Basin Planner. At the Federal Energy Regulatory Commission (FERC), he is responsible for the development of Hydropower Resources Assessment in the Division of River Basins.

Mr. McConnell received the B.S. degree from the University of Delaware. He worked for the engineering consulting firm of Bernard Johnson, Inc., as a Flood Study Analyst. At FERC, he assists with the development of Hydropower Resources Assessment in the Division of River Basins.

MINIMIZING CAPITAL COST IN SMALL-SCALE HYDRO DEVELOPMENT

Malcolm R. Vanderburgh and David C. Willett

The rekindled interest in development of renewable energy resources has encouraged a large number of entrepreneurs, utilities, governmental agencies, engineers and contractors to proceed with a variety of small hydro projects. The majority of these projects will require significant capital funding, a problem which relates closely to some of the reasons for the historical decline of small-scale hydro. One of the most important of these factors was the relatively high investment cost per installed kilowatt for new equipment for these older, smaller plants, rendering them uneconomic compared to the new and larger thermal generating units which were the products of a later technology. Regardless of the enthusiasm of the proposers, therefore development schemes for these small-scale hydro projects must effectively deal with this basic problem—minimizing the capital cost of the equipment and associated structures.

The cost of turbine and generator equipment usually represents 55 to 65 percent of the direct capital cost of a small hydro project. Two basic factors have combined to significantly increase the capital cost of this equipment. Firstly, the practice of developing optimized solutions for the numbers, types and capacities of turbine/generator units has resulted in unique designs for each project, each requiring substantial design and development costs. In addition, the influence of "large unit" technology has led to the requirement for sophisticated unit control and redundant protection systems, often without regard for the relationship of the particular unit to the size of the connected system.

These factors have a cascading effect on the cost of the associated structures and on the cost and complexity of the electrical and mechanical services. More importantly, if not evaluated in an informed and competent manner during the feasibility stage, they can result in progressive cost increases during subsequent phases of the project, with serious adverse effects on the economic viability of the committed development.

This paper outlines a philosophy for small-scale hydro development emphasizing minimum capital cost, and presents a number of examples of cost-saving measures instituted on current small-scale hydro projects.

ABOUT THE AUTHORS: Mr. Vanderburgh is currently project manager for four small-scale hydro projects in New York State. Mr. Willett is responsible for the overall direction of Acres' Hydro and Heavy Civil Division, which is currently undertaking small-scale hydro projects in New York, Nebraska, Vermont, Massachusetts, Maryland, Virginia and South Carolina. The authors are employed by Acres American Incorporated, Liberty Bank Building, Main at Court Streets, Buffalo, New York.

Session Twenty

ENGINEERING

Topic: Development and Operation Economics

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A BASIC ECONOMIC COMPARISON OF SMALL-SCALE HYDROELECTRIC BUSBAR COSTS

James P. Searls

The historic costs of smaller sized hydroelectric sites in the FERC Area I were analyzed for installation cost trends. Two 12.5 MW examples were interpolated. Fixed annual charge rates for four possible developers were derived. The fixed annual charges and the operation and maintenance costs were combined to develop busbar costs according to capacity factors. These are compared to alternative technology costs to investigate the developers and types of sites that could presently consider a 12.5 MW site.

The TAMS data were used to extend the busbar cost down to the 300 kW region. Finally the barriers to small-scale hydroelectric development is briefly reviewed.

ABOUT THE AUTHOR: Mr. Searls received the B.S. in Physics from St. Louis University in 1966 and the M.A. in Economics from the Pennsylvania State University in 1977. He worked for the Electric Power Research Institute for two years as a resource economist and is a power analyst—DOE, Resource Applications, Plans, Programs, and Analysis Office, Washington, D.C.

ECONOMIC EVALUATION OF SMALL-SCALE HYDROPOWER PLANTS

Alvin S. Goodman

The benefits of increased efficiency at a hydroelectric plant will be equal to the sum of the capacity and energy values of the increased generation. A preliminary estimate of these component values may be based on generalized estimates of the value of electrical power which the Federal Energy Regulatory Commission has prepared for each of its regions.

A better estimate is obtained by a careful analysis of specific generating plants and the electrical systems receiving their energy. This is because the capacity and energy values will depend (to a very large extent) on the amounts and timing of the hydro generation, the kind of power utility (public or private) or other recipient of the generation, and the nature of the electrical system. The benefits for a given amount of power would differ from one location to another. Any generalized approach to estimating these benefits, would have to be based upon studies of generation regimens at representative plants.

This paper discusses the generalized techniques of economic analysis to an inventory of all existing and potential hydropower sites in the State of New York, in a project sponsored by the N.Y. State Energy Research and Development Authority. Preliminary cost estimates and the preparation of a Developer's Manual with suggested approaches for the determination of preliminary economic feasibility by the developer were included.

This paper also discusses the application of economic criteria to screen all identified sites in New England to determine commercial viable hydroelectric potential in a project sponsored by the utilities of the New England Power Pool.

The effect on economic analyses of increasing costs of imported fuel is discussed. Adjustments to the benefit/cost analysis are appropriate if hydropower benefits are considered in terms of equivalent thermal generation costs, and if the price of oil is expected to advance at a more rapid rate than the general inflation rate.

ABOUT THE AUTHOR: Dr. Goodman received the Bachelor's degree in Civil Engineering from the City College of New York and the Master's degree from Columbia University with a major in hydraulic engineering. He completed the Ph.D. degree with a thesis in environmental systems at New York University. At the Polytechnic Institute of New York, he is the coordinator of the Water Resources Program. He has been a Staff Consultant since 1962 in water resources planning and economic evaluations for Tippetts-Abbett-McCarthy-Stratton, New York, New York.

A CONCEPTUAL ECONOMIC MODEL OF SMALL-SCALE RUN-OF-RIVER HYDROELECTRIC FACILITIES

Donald W. Lystra

The economics of small-scale run-of-river hydroelectric facilities are unique from those of other capital investment projects. Although cost curves exhibit the familiar S-shape associated with increasing productive capacity, revenue curves are distinguished by having a continually declining rate of increase, and of being bounded by an upper limit related to available stream discharge.

This can be illustrated graphically as a series of curves which represent the theoretical relationships between project costs, revenues, and benefit/cost ratios, as functions of plant productive capacity. Civil/structural works costs are observed to start at a high initial level, but to show relative insensitivity to increasing capacity. Equipment costs begin at a low initial level and increase with facility size at a slightly less than proportionate rate. The revenue curve starts at zero, increases sharply as low magnitude streamflows are utilized, and then becomes quite flat as the water power potential begins to be fully utilized.

The optimum plant capacity can be defined as the point where marginal costs equal marginal revenues. For small hydroelectric projects this is the plant capacity which will generate sufficient revenue to optimally amortize the initial civil and structural costs, plus the variable cost associated with equipment capacity, subject to declining revenue rates.

There are two alternative approaches to identifying this optimum point for specific projects. The first is to actually calculate incremental benefit/cost ratios for alternative plant designs, based on actual cost estimates and revenue projections. The second approach involves the expression of project cost and revenue functions in mathematical terms. With this information it is possible not only to identify an optimum plant capacity, but to define a range of acceptable capacities based upon different rate-of-return requirements of investors. The difficulty with the second, more rigorous approach is to find a tractable expression for the flow-duration curve, which is the basis of project revenues. Several recommended techniques can be offered, including several that have been successfully used in the analysis of flood events.

ABOUT THE AUTHOR: Mr. Lystra received the B.S.E.(EE) degree from the University of Michigan in 1968 and the M.A. degree in Mathematical Sociology from the same school in 1975. Mr. Lystra has served as Project Manager on several small-hydro feasibility studies and is currently Project Manager on two hydroelectric construction projects. He is Head, Electrical Department—Ayres, Lewis, Norris & May, Inc., Ann Arbor, Michigan.

COMPARATIVE PROJECT ECONOMICS OF SMALL-SCALE HYDRO

Kemal Satir and Howard A. Mayo, Jr.

Changing Federal Government incentives are encouraging development of higher-head hydroelectric power sites. Such sites can provide more economical power and minimum environmental impact. Because the physical requirements for higher heads are substantially different, the economic optimization opportunities fall into different construction areas.

Evaluation of the site—specific capacity and energy produced is substantially influenced by environmental considerations. The increasing value of power produced will make smaller flows and lower heads economical; however, the higher-head sites will inherently be physically smaller and lower cost for a given output. Since standardization of equipment for higher-head Francis and Impulse turbines is more costly, potential cost reductions may be more significant in other areas.

Typical illustrations of existing projects provide a general review of the substantial existing experience.

ABOUT THE AUTHORS: Mr. Satir received the B.S. degree from the Engineering Academy, Yildiz, Istanbul, Turkey. The M.S. degree in Electrical Engineering was received from the University of Michigan, Ann Arbor. Prior to his present activity, he was Chief Engineer for Inland Power & Light Company, Spokane, Washington. Presently, Mr. Satir serves as an Electric Utility Consultant in areas of System Studies, Planning and Management. He is listed in Who's Who in the United States and in the West.

Mr. Mayo received the B.S. degree from Worcester Polytechnic Institute, Worcester, Massachusetts. At the Allis-Chalmers Hydro-Turbine Division, he is responsible for market development for the Standard Products and Customer Service Department which includes water control products such as Bascule gates and Howell-Bunger valves in addition to small hydroelectric units and standardized hydroelectric units. Mr. Mayo is largely responsible for the development and promotion of the TUBE turbine unit and its sale in North America. He holds several U.S. and foreign patents relating to hydraulic machinery, has presented numerous technical papers and has contributed to several text books on the subject of hydraulic machinery.

Session Twenty-One

ENGINEERING

Topic: New Ideas, Concepts, and Technology II

Chairman: Howard A. Mayo, Jr.
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IDENTIFICATION OF NECESSARY HYDROELECTRIC RESEARCH IN SUPPORT OF SMALL-SCALE AND LARGE-SCALE DEVELOPMENTS BY ELECTRIC POWER RESEARCH INSTITUTE

Antonio Ferreira

Hydroelectric generation accounts for 10% to 13% of the electric energy generated in the United States. As alternative energy resource costs soar, the value of this resource and utility interest in reconditioning and rehabilitating old plants and in building new plants have correspondingly and substantially increased. This renewed utility interest and cognizance of the necessity to reduce capital and O&M costs is surfacing many design, engineering, construction, operation and maintenance problems which are best resolved on an industry coordinated basis.

The Electric Power Research Institute staff, supplemented by consulting services, has initiated a program of identification, prioritization and development of projects and studies to address the following types of generic research, development and demonstration objectives: (1) advance the state-of-the-art of hydroelectric technology, including the extrapolation of pump/turbine technology to higher heads, larger unit sizes with regulating ability; (2) improve the performance, reliability, and the availability of existing and new generating units; (3) improve the safety and reliability of existing and new dams and other water impounding and transfer structures; (4) reduce capital, operating, and maintenance costs of hydroelectric facilities; (5) assess, evaluate, and improve utilization of hydroelectric resources and increase public and environmental acceptability of hydroelectric facilities.

The broad objectives will be addressed by selected projects and studies dependent and determined by evaluation and availability of appropriate contract teams and the identified relative priorities and benefits to the industry. The procedures and methodologies will include the use of standard and straightforward design and engineering analyses as well as development of new computer-aided techniques and hydraulic model studies, a simplified methodology for economic screening and increasing plant efficiencies.

ABOUT THE AUTHOR: Mr. Ferreira received the B.S.C.E. from the University of Massachusetts. He has been involved in hydroelectric functions for Northeast Utilities since 1951, including Project Management responsibility for the 1,000 MW Northfield Mountain pumped-storage project. Currently, Mr. Ferreira is on special assignment to the Electric Power Research Institute, West Springfield, Massachusetts, managing compressed air and underground pumped hydro storage projects, and the hydroelectric research program.

THE VERTICAL HYDRAULIC RAM—A LOW-HEAD HIGH-FLOW DEVICE FOR POWER DEVELOPMENT DESIGN OUTLINE FOR A 1,000 kW PLANT FOR A SIX-FOOT HEAD

Hamilton Baird

Hydropower developers have not found that low-head sites are attractive for development; they find that the power output is low and that the cost of the turbine itself is practically as great as the cost of a turbine of equal diameter designed for a higher head.

Actually the hydraulic ram is capable of performing the hydraulic conversion from a low to a higher head, and it is capable of operating at hydraulic efficiencies in the 90% range. A full description of its operation can be found in the older encyclopedias and the older engineer's handbooks.

Many attempts have been made to design the hydraulic ram on a large scale but without real success. The challenge is to redesign the ram in a manner which will permit the scaling up to power development sizes while retaining the essential principles of the ram, namely an employment of the forces of gravitation and acceleration with abrupt reduction of the rate of flow to zero.

A number of working models have been made and tested, on two occasions with the assistance of grants-in-aid from the National Research Council, and generous assistance has been provided by a number of distinguished authorities in related scientific and engineering fields.

In this paper the writer presents the concept of the Vertical Hydraulic Ram making use of the low-head energy in rivers and possibly in tidal or ocean wave situations.

The mechanism is described, with illustrations, and the contour of a 1,000 kW run-of-the-river 6-foot head hydro plant, is illustrated. Particular attention is given to the question of the hydraulic efficiency of this type of ram.

ABOUT THE AUTHOR: Mr. Baird holds the B. Com degree from Dalhousie University in Halifax. He is retired, having spent a number of years in employment on major construction projects and in the sale and installation of electrical and mechanical equipment. He resides at 191 Bonaccord Street, Moncton, New Brunswick, Canada.

HYDROELECTRIC DEVELOPMENT, WITHOUT DAMS, RESERVOIRS AND PENSTOCKS

Phillip R. Hoffman

Wherever a water distribution system has large variations in elevation there is a requirement to control the pressure of water delivered to the customers. This is generally accomplished by a "pressure regulating station" located typically in a vault beneath the street pavement. This article discusses a simple scheme to recover this presently wasted energy by installation of a hydraulic turbine just upstream from or in parallel with the regulating station. Many such installations would each produce hundreds of kilowatts, each eliminating the wastage of thousands of barrels of oil per year. The environment would be greatly benefitted and it is extremely cost effective.

ABOUT THE AUTHOR: Mr. Hoffman received the B.S. and M.S. degrees from the University of Southern California. As Resources Research Engineer for the Power System of the Los Angeles Department of Water and Power he developed the basic concept, design and economics for the recently completed Castaic Pumped Hydro Project, 1,250,000 kW. After his retirement from the Department in 1974 he became a consultant, on small hydroelectric development, to a number of Architect/Engineer companies and several large irrigation districts.

APPROPRIATE TECHNOLOGY IN HYDROPOWER

Rene Tegtmeyer

The U.S. Patent System has created not only an incentive to innovate, but an invaluable information resource, as well. A product of this system, as old as the country itself, the U.S. Patent File has become a national resource. This file, available to the public, now contains over 4.1 million distinct U.S. patents, each bound by law to include a fully detailed technical disclosure, and categorized and cross-referenced by technology in an extensive classification system which covers virtually every technical field. These patents and cross-references, taken with millions of similarly categorized foreign patents and other technical documents, represent a unique collection of technical information particularly valuable to small-scale industries, local governments, and developing countries—all with special needs for appropriate technology, but generally having insufficient resources to develop their own.

Invention disclosures involving components of power generation systems, e.g., motor/generators, electrical transmission, and pumps, have numbered in the thousands each year. Patent activity in overall hydropower systems and major components has not been high, but has experienced recent moderate upturn.

In their search for technology appropriate to particular projects, hydropower system planners should look to the continuously growing Patent File—a vast storehouse of information from around the world.

ABOUT THE AUTHOR: Mr. Tegtmeyer is Assistant Commissioner for Patents, U.S. Patent and Trademark Office.

nning, Information and Methods Sessions

Session Seven

PLANNING, INFORMATION AND METHODS

Topic: Social and Environmental Analyses I

Chairman: Bernhard Richert
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COMMUNITY AND SOCIAL IMPACTS FROM HYDROPOWER DEVELOPMENT

Shirlene Clemence

Earlier this year, President Carter, in his series of energy speeches, stressed the need to develop our nation's energy resources—both renewable and nonrenewable—as expeditiously as possible. Immediately following this announcement, many public interest groups expressed concern that environmental and social considerations would decline under the impetus to develop national energy resources.

Certainly, many energy-rich regions are not only environmentally sensitive but are cherished by local residents. But the recipients of new power generation are often not local residents, but rather people residing in dense population centers sometimes hundreds of miles away. The public today is asking tough questions: Are the projects necessary? Why in our backyards instead of yours? Why do we have to suffer so that you can live comfortably? Aren't there other ways to produce this energy?

There are no easy answers, and no doubt projects will continue to be questioned and possibly delayed. But there is a way to minimize public dissatisfaction and opposition. If you've ever had a Big Mac at the McDonald's hamburger chain, you've seen it in practice. What is McDonald's key to success? They "Do It Right." McDonald's management does not just listen to their customers, they actively consult with them and are responsive not only to food preferences and dining atmosphere, but also consider local traditions and values and endeavor to enhance local communities.

Creative public involvement does not necessarily mean that the public will support a project. However, a very important result can often be improved relations between the project organization and the public. A good relationship can lead to good communication, avoid misunderstandings, and often result in adverse impacts being prevented or adequately mitigated. This is desirable, particularly if the organization has frequent contact with the people involved or if it intends to propose other projects in that area.

The challenge before us is clear: to develop our energy resources with minimal delay. In addition to assessing the technical, economic, and even biophysical aspects of a project, the human element has to be included. Involving the local residents early in the process at the scoping level, and demonstrating sensitivity, flexibility, and responsiveness, can result in fewer project delays, decreased cost overruns and can bring us closer to achieving our national goal of energy independence.

ABOUT THE AUTHOR: Ms. Clemence has a B.A. in Social Welfare, and a B.S. and a M.S. in Civil Engineering from the University of Washington, Seattle. Presently she is a Civil Engineer with the U.S. Army Corps of Engineers, Seattle District, Washington.

FISH PASSAGE AND SMALL HYDROELECTRIC TECHNOLOGY: A STATE OF THE ART REVIEW

Milo C. Bell and Stephen G. Hildebrand

One of the most frequently raised environmental issues relating to the development of small hydroelectric technology is the possible requirement of fish passage facilities at individual sites. Fish passage facilities may be a significant factor in determining economic feasibility of small hydro projects. We discuss here our analysis of the literature and experience in the United States regarding available technology to pass both upstream migrating adults and downstream migrating young fish around dams.

The technology and expertise is currently available to design successful fish passage facilities. However, site-specific analysis is required to optimize basic engineering criteria and biological parameters that will successfully pass the species of interest. These criteria are discussed for the three major systems currently in use for passing adults upstream (fishways, fish locks, and fish elevators), and for two types of fish screens for handling downstream migrating fish.

The construction and operation of fish passage facilities can affect small hydro development by increasing capital expenditures, annual operating costs, and water demands. General cost estimates for certain fish passage facilities are presented. The need for fish passage facilities at small hydro sites will depend on the fish species inhabiting the area, initiatives to redevelop or enhance fisheries, and current regulatory goals. If fish passage facilities are required or desired, it is crucial that the design of such facilities be an integral part of conceptual design and evaluation of a project.

ABOUT THE AUTHORS: Professor Bell received the B.S. in Mechanical Engineering from the University of Washington. His experience in the area of fish passage includes professor, Chief Engineer (Univ. Wash. Dept. Fisheries, International Pacific Salmon Commission) and consulting engineer for Federal, state, and local agencies and private companies. He is Professor Emeritus, University of Washington, College of Fisheries, Seattle, Washington.

Dr. Hildebrand (Ph.D. Fisheries, Michigan) is currently assessing environmental issues relating to small hydro technology. His experience includes environmental research and assessment of nuclear and fossil fuel cycles. He is a member of the Research Staff, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

SMALL-SCALE HYDRO—AN OPPORTUNITY FOR HISTORIC PRESERVATION

Richard T. Heiderstadt and William J. Novak

Many existing small hydroelectric projects were built in the late 19th and early 20th centuries, and some were built on sites which were previously used to generate mechanical power in the late 18th and early 19th centuries. The buildings which house these plants are often of historic and scenic interest.

A review of available information on existing small hydroelectric plants has shown that the historic significance of many of these projects has not been fully recognized. The power house structures often represent fine examples of early American industrial architecture. These historic resources are found in both rural and urban locations and are often in proximity to older industrial areas which have been, or have the potential to be, developed into historic districts.

Existing small hydroelectric projects fall into two categories. Plants which are currently in operation, and projects which have ceased operation for one reason or another but which have the potential for renewed power generation. Both types of sites offer opportunities for development of significant historic resources.

An example of a project which is not currently in operation but which could be placed back into operation is the Frog Hollow Mill Hydroelectric Plant in Middlebury, Vermont. This plant was built in 1917 and operated continuously until 1964 at which time it ceased operations and was partially dismantled. The site itself was first used to produce mechanical power in the late 1700s. A recent feasibility study concluded that this project is suitable for a renewed generation of electrical power, and that it would be compatible with the continued development of the area's historic and scenic resources.

Existing small hydropower facilities offer an opportunity to preserve and make accessible to the public an important part of our industrial heritage. Development possibilities range from passive visual or aesthetic enhancement through provision of interpretive exhibits to active programs allowing public access to power house facilities.

ABOUT THE AUTHORS: Mr. Heiderstadt received the B.S. degree from Iowa State University and a Masters degree in City and Regional Planning from Rutgers University. He is Chief Environmental Planner at the TAMS Washington, D.C., office and is involved in all phases of environmental studies associated with the development of water resources projects.

Mr. Novak, Senior Environmental Planner with TAMS, received the B.A. degree in Geography from Kent State University and the M.A. degree in Geography from the University of Texas. At present Mr. Novak is conducting environmental analyses on a wide range of projects including hydroelectric facilities, highway systems, and military installations.

Session Eight

PLANNING, INFORMATION AND METHODS

Topic: Planning for Development I

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LOW-HEAD HYDROELECTRIC EVALUATION AND INVENTORY OF THE SEVENTEEN WESTERN STATES

Nelson J. Jacobs

A report of the status of an evaluation and inventory of the potential for low-head hydroelectric development in the Western United States is presented in this paper. The study is being done in three phases.

Phase I is an evaluation of the potential for low-head hydroelectric development at existing Water and Power Resources Service, (formerly Bureau of Reclamation) project facilities, including dams and water conveyance structures. This phase is completed and the paper presents the methodology used and the results obtained from this part of the study.

Phase II is a general inventory of potential low-head hydroelectric development sites. This phase is in progress and is scheduled to be completed by late 1980. The inventory will consist of all existing low-head dams, all previously identified potential low-head sites, and sites not previously evaluated. A comparative evaluation of all sites will be made and a prioritized listing of the sites will be produced. Maximum use will be made of the data base generated by the Corps of Engineers during their National Hydropower Study. The study procedures and criteria are described and the current status of the work is reported.

Phase III will be a more detailed evaluation of a number of sites included in the Phase II inventory. These will be sites that appear to be potential Federal developments. This phase of the study will be carried out during 1981. The proposed procedures for this phase are presented in the paper.

ABOUT THE AUTHOR: Mr. Jacobs received the B.S. degree in Civil Engineering from Michigan State University. At the Water and Power Resources Service (WPRC), formerly the Bureau of Reclamation, Denver, Colorado, he is responsible for coordination of power planning activities between WPRC's field offices and other agencies, and the Engineering and Research Center. He is WPRC's member representative to the Planning Coordination Committee of the Western Systems Coordinating Council, principal investigator for special studies of small hydro and pumped storage being done cooperatively with the Department of Energy and study coordinator for WPRC's Low-Head Hydroelectric Evaluation and Inventory.

METHODOLOGY FOR CONDUCTING A RESOURCE ASSESSMENT OF SMALL-SCALE HYDROPOWER POTENTIAL

Thomas E. Klock

Vitally important to policy making on water resource use is the determination of the potential that exists for hydropower development as well as water resource impacts that would result. This particularly applies to regions where opportunities abound for developing small-scale hydropower facilities either at existing dams or at new dam sites. However, making these determinations on a large scale can be extremely costly and complex. To overcome these obstacles, a planning methodology has been developed for conducting a regionwide or river basin resource assessment of hydropower potential. The methodology has proven to be workable and has produced the desired firstcut, or planning-level findings which can support policy-level decisions without requiring detailed engineering evaluations.

The methodology calls for the assembly of a minimal amount of data from readily-available sources and the utilization of Federal, state, and regional agency personnel wherever possible. Computer capabilities are incorporated through use of screenings to reflect hydrologic, hydraulic, and economic constraints. Comparisons are made for areas where new small-site development would foreclose opportunities for retrofitting existing dams. Impacts on competing or conflicting water resource uses are assessed through analysis of a socio-environmental data baseline. Computer simulation is then used to evaluate the effects of alternative future scenarios on hydropower development and water resource policies.

Implementing the resource assessment methodology in New England has produced findings which show where efforts should be focused to expand the use of small-scale hydropower facilities. Other findings should enable the region to decide among water-resource management choices where adverse impacts on competing water uses would be created. The methodology has already proven effective in that the time and expense of selecting feasible sites has been significantly reduced. Added benefits should occur, as competing water use issues have been identified and can be given needed attention either before or at an early point in the permitting and licensing process.

ABOUT THE AUTHOR: Mr. Klock received a degree in Civil Engineering from Lafayette College and has done graduate work at the University of Southern California and Pennsylvania State University. At New England River Basins Commission (NERBC), he has served as Chairman of the Task Force on Flood Plain Management and has been involved in a number of other water resources planning activities. He also has extensive administrative and consulting experience in the fields of engineering and planning. He is Study Manager, NERBC, Boston, Massachusetts.

SCREENING STUDIES FOR SMALL-SCALE HYDROPOWER

Alexander C. George

For the purpose of this discussion a "Screening Study" is defined as the rapid and inexpensive review of previously recorded data for a large number of existing dams and proposed damsites and identification of the potentially viable sites for the given potential developer.

The aim is to develop a listing of sites which appear to offer the best chance of proving viable and warrant the expenditure of "front-end risk" money on a full feasibility study.

Factors requiring to be considered in such a study include technical, cost and economic criteria. This paper will attempt to review the selection and use of these criteria so that the final listing has not discarded good sites in error while reducing the sites to receive further review to a manageable number.

In developing screening procedures it is possible to include checkpoints. Many existing sites are known to be fully developed and average annual generation values are available. Also the results of recent full feasibility studies for known sites can be found. Comparison of these values with the results of the screening procedures can provide adequate checks.

ABOUT THE AUTHOR: Mr. George graduated in Civil Engineering from the Sydney Technical College, Sydney, Australia in 1954. He commenced work in hydroelectric engineering in 1957 and has participated in many water resources projects since that time, with an emphasis on the feasibility, layout and design of power plants. As Principal Civil Engineer, Tippetts-Abbett-McCarthy-Stratton, New York, New York, he has recently completed numerous feasibility studies and a screening study which commenced with 11,000 identified sites.

INTERAGENCY COORDINATION FOR SMALL HYDROELECTRIC POWER DEVELOPMENT IN ALASKA

Loran R. Baxter and Weldon A. Opp

In October 1976 the Chief of Engineers was directed by the Committee on Public Works, United States Senate, to determine the feasibility of installing small-scale hydroelectric units, 5 MW or less, in isolated communities throughout the State of Alaska. The primary objective of the study was to reduce the dependence upon diesel generation with its ever increasing costs.

The Alaska District has undertaken a reconnaissance study to determine which villages and communities throughout the State do have a potential for the development of small hydropower. From the preliminary findings of the reconnaissance report, the communities with greatest potential will be singled out for feasibility studies.

Through close coordination with the U.S. Department of Energy's Alaska Power Administration, the State Division of Energy and Power Development, and the Alaska Power Authority, a systematic approach is being developed to assess the hydro potential throughout Alaska. Funding and manpower limitations, coupled with various organizational constraints, has motivated the various agencies to work closely together attempting to meet the power needs of the many isolated villages.

Utilization of a region by region approach, with provisions for helping individual communities on a request basis, has helped to optimize funding capabilities during this first year of the study. By taking this approach, an assessment of the hydro potential for all small Southeast Alaskan communities was made possible as well as various other communities throughout the State.

ABOUT THE AUTHORS: Mr. Baxter received the Bachelor of Science in Civil Engineering from the University of Washington. He is currently employed with the Alaska District Corps of Engineers as a water resource planner. At present he is the project manager for a hydropower feasibility study at Valdez, Alaska in addition to managing the statewide Small Hydropower Study.

Mr. Opp received the B.S. degree from Walla Walla College and M.S. from the University of Alaska. Presently the Alaska District Chief of Civil Works, prior to 1974 he was the Civil Works Project Coordinator for the Snettisham Hydroelectric Project near Juneau, Alaska.

Session Nine

PLANNING, INFORMATION AND METHODS

Topic: Case Studies and Demonstration Projects I

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FEASIBILITY INVESTIGATIONS OF FIVE LOW-HEAD HYDROELECTRIC PROJECTS UNDER DOE GRANT PROGRAM

James V. Williamson and A. Wayne Pietz

Studies were performed under a Department of Energy (DOE) grant program to assess the feasibility of installing low-head hydroelectric generating facilities at five existing dams in the United States.

The proposed hydroelectric projects are Tuttle Creek, with a 14,750 kW installation under a rated head of 60 feet at an existing Corps of Engineers flood control dam and reservoir, for Kansas Electric Power Cooperative, Inc., of Topeka, Kansas; Zumbro, with the addition of a third unit of 1,800 kW in an empty bay in an existing powerhouse, with a rated head of 52 feet, for the City of Rochester, Minnesota; Piqua, with a 400 kW installation under a rated head of 8 feet at an existing concrete dam impounding a cooling water pond, for the City of Piqua, Ohio; Maxwell, at the existing Corps of Engineers Locks and Dam on the Monongahela River, with an installation of 000 kW with a rated head of 17 feet, for Allegheny Electric Cooperative, Inc., of Harrisburg, Pennsylvania; and Jackson Bluff, with an 8,000 kW installation under a rated head of 32 feet at the existing decommissioned powerhouse at Jackson Bluff Dam, for the City of Tallahassee, Florida.

Studies were performed to determine the annual benefits and costs of each project which established a basis for assessing the economic feasibility of each project. The Jackson Bluff and Zumbro Projects showed first year benefit-cost ratios equal to or greater than one, and substantial savings over the first ten years of operation on a present worth basis, which indicates conclusive economic feasibility. The Tuttle Creek and Maxwell Projects were found to show economic feasibility based on a ten-year present worth analysis, assuming low interest (7% or less), Rural Electrification Administration type financing can be obtained. The Piqua Dam Project was found to be unfeasible.

ABOUT THE AUTHORS: Mr. Williamson received the B.C.E. (Civil Engineering) degree from Melbourne University, Australia and has 30 years experience in all phases of many water resource projects, including hydroelectric, water supply and flood control projects and other major multipurpose projects. He is Partner and Assistant Manager, Western Design Office—R. W. Beck and Associates.

Mr. Pietz received the B.S.C.E. (Civil Engineering) degree from the University of Washington and has been engaged in the planning, feasibility, design and construction of major water resources projects for over 5 years. He is Supervising Engineer—R. W. Beck and Associates, 200 Tower Building, Seattle, Washington.

POWERHOUSE RESTORATION AT HAGLEY

Lee DeHeer

Located 2 miles north of Wilmington, Delaware, on the banks of the Brandywine Creek, the Hagley Museum is historically significant. Situated at the site of the original powder works established by E. I. duPont in 1802, the existing facilities are a testament to man's ability to harness the forces of moving water.

The New Century Power House was built ca. 1900, employing three forty-four-inch Rechard water turbines to run several dynamos. Electricity from these dynamos was used throughout the powder yards for lighting and motors. This installation continued in use until about 1921.

In an effort to meet the energy crisis of the 1970's, the Hagley Foundation again tapped the Brandywine as a source of power. Construction for a hydroelectric generating plant was begun in late 1975 on the site of the New Century Power House. The Foundation purchased a 54-inch Smith-Kaplan turbine and 300 kW General Electric generator, originally custom-made for the 1932 Winter Olympics at Lake Placid, New York. The unit was modified to produce up to 500 kW of power.

By using an alternate millrace, the head of water available was raised from nine feet to twenty-eight feet. A six-foot diameter penstock was constructed underground between the millrace and the powerhouse. This plant was commissioned October 4, 1976. Initial power production was limited to about 225 kW.

With increasing power demands and costs, investigations were made to evaluate potential power production increases with respect to improved hydraulic conditions in the water supply system. In early 1979, construction was completed without major interruption to Museum activities. Hydraulic conditions were improved by realigning the millrace and modifying the penstock entrance. The results to date have been impressive. Further improvements to the system are being delayed until a full evaluation of the recent improvements can be made.

ABOUT THE AUTHOR: Mr. DeHeer received the B.S.C.E. degree from the University of Michigan in 1961. He was an engineer with Bechtel Corporation in San Francisco from 1961 to 1964 and with the Contuz Costa County Flood Control District from 1964 to 1969. He has been with O'Brien and Gere Engineers, Inc. at Philadelphia, since 1969 where he is currently Managing Engineer of the Water Resources Group.

IDAHO FALLS LOW-HEAD HYDROELECTRIC DEMONSTRATION PROJECT SELECTION OF UNIT SIZE

Pablo Chavez

The City of Idaho Falls is redeveloping its three hydroelectric power plants located on the Snake River in and near Idaho Falls, Idaho, using bulb turbine-generators. The project is a key element in the United States Department of Energy (DOE) national low-head hydroelectric demonstration program. The project will demonstrate that, under appropriate conditions, the application of bulb turbine-generator technology is an economically viable and environmentally acceptable means of developing new sites, or upgrading existing hydroelectric facilities to increase their energy generation. This technology can be applied immediately, without prior research or development.

Bulb units were selected for the Idaho Falls installations based on comparison with Kaplan turbines. This comparison which was based on the same rated output, efficiencies and head, showed that the bulb turbine has numerous advantages over the Kaplan.

Layouts of powerhouses at one of the sites for both types of machines showed that a savings of more than 40 percent in the cost of the civil works would result. The main economic advantage of using bulb turbines at Idaho Falls therefore is the large savings possible in the initial construction costs.

The bulb turbine is the optimum turbine-generator unit for the low-head, run-of-river conditions existing at Idaho Falls. With a carefully written specification and a reliable manufacturer, the bulb turbine will give the best possible economic return under the conditions existing at the Idaho Falls sites.

The reliability of bulb units has been well demonstrated in Europe. This type of machine is starting to appear in the United States and should lead to valuable economic exploitation of low-head hydro reserves.

This paper will also present the results of studies made to select the unit size for the Idaho Falls installations considering water availability, estimated costs for furnishing and installing the units, the value of power benefits established for the project and estimated construction costs.

ABOUT THE AUTHOR: Mr. Chavez received the B.S. degree from the University of New Mexico. He is a licensed professional engineer in California and Idaho. He has more than 23 years experience in the planning and design of water resources projects and in the design of major hydraulic structures. Mr. Chavez is the Project Manager on the Idaho Falls Hydroelectric Project.

Session Fifteen

PLANNING, INFORMATION AND METHODS

Topic: Social and Environmental Analyses II

Chairman: Allan Hirsch
Director, Office of Biological Services
U.S. Fish and Wildlife Service
Department of the Interior
Washington, D.C. 20240

TAPPING THE BOUNDLESS RESOURCE TO SOLVE ENERGY PROBLEMS

Roger E. Hamlin

In an era of energy and resource shortage the human resource must receive maximum utilization. The human resource is called boundless because, instead of depleting with consumption, human labor improves when appropriately utilized. Individuals learn skills and apply their mental capacities as they gain experience. The human resource is also a perishable resource. If an individual spends a week unemployed, that man-week of skill and training can never again be captured.

Despite the nature of the boundless resource, millions of individuals remain unemployed. We are now entering a period of stagflation in which energy costs and unemployment problems are being exacerbated. One partial solution to both problems is to employ unemployed individuals on the retrofitting of abandoned low-head hydroelectric facilities. But because of the difficulty of both tasks, combining them is a complicated endeavor. The purpose of this paper is to describe a system for employing and training unemployed youth while rehabilitating a small dam and preparing it for hydroelectric production. This system has been designed over the past year, is being tried at one site, and will be tested at ten additional sites over the next two years.

The purpose of this paper is to describe the potential for combining the employment of unemployment individuals with the promotion of hydroelectric production. This description will not be theoretical but will be couched in terms of immediate implementation strategies including funding sources. The first part of the paper discusses the background and history of both relevant problems with emphasis on how unemployment and low-head hydro potential are geographically and economically related. Part two describes the current national demonstration project including both past results and future directions, and part three provides a how-to-do-it approach to project implementation.

ABOUT THE AUTHOR: Dr. Hamlin is an Associate Professor of Urban Planning at Michigan State University, East Lansing, Michigan and Vice President of the Proaction Institute, where he is directing the Youth and Energy Project. He has been on the faculty of Columbus College and Syracuse University, worked for the New York State Senate and Office of Planning Services, a South American ministry of housing and urban affairs, and several local community development agencies. He holds a doctorate in Economics and Public Administration from the Maxwell School at Syracuse University.

THE USE OF IMPACT MATRIX METHODOLOGY TO ASSESS THE ENVIRONMENTAL IMPACT OF SMALL-SCALE HYDROELECTRIC PROJECTS

Richard K. Carlisle and Donald W. Lystra

A key component in the assessment of the feasibility of small-scale hydroelectric projects is the evaluation of environmental impacts related to alternative design or operational strategies, or to development vs. nondevelopment options. This evaluation is complicated by the quantity of interactions which can theoretically exist between a large number of proposed activities and a large number of environmental factors. The assessment process runs the risk of becoming mired in detail, or of having apparently major impacts obscure lesser, but equally critical, impacts.

The impact matrix assessment methodology helps to make these problems manageable by providing a structured, systematic approach to the identification and evaluation of interactions between a proposed hydroelectric facility and the environment. The impact matrix is itself nothing more than a gridlike device having proposed activities arrayed along one axis and environmental factors arrayed along the other axis. In the instance of small-scale hydroelectric projects it is helpful to divide proposed activities into two categories: those relating to construction and those relating to operation. Environmental factors include all natural, social, economic, and legal/institutional phenoma which constitute the baseline statement for the project area.

Environmental assessment with the impact matrix then becomes a two-step process. The first step is the comprehensive identification of potential interactions between proposed actions and environmental factors. The second step involves a detailed analysis of each interaction, followed by analysis and summerizations.

The impact matrix procedure has been used by the authors to assess the environmental impacts of various design alternatives on three small-scale hydroelectric projects in Michigan. An important side-benefit has been found to be that it provides a format for fruitful discussions between interested groups and facilitates communication between technical and environmental specialists. At the present time, the authors are working to standardize the device and to develop a satisfactory means to quantitatively evaluate the relative impacts of alternative courses of action.

ABOUT THE AUTHORS: Mr. Carlisle received the B.S. degree from Miami University and the M.S. in Regional Planning and Resource Development from Ohio State University in 1974.

Mr. Lystra received the B.S.E.(EE) degree from the University of Michigan and the M.A. degree in Mathematical Sociology from the same school.

Mr. Carlisle is Head, Planning Department, and Mr. Lystra is Head, Electrical Department—Ayres, Lewis, Norris & May, Inc., 3983 Research Park Drive, Ann Arbor, Michigan.

ANALYSIS OF ENVIRONMENTAL IMPACTS OF WATER LEVEL FLUCTUATION AT HYDROELECTRIC SITES

Adam T. Szluha, James M. Loar, Ralph R. Turner, and Stephen G. Hildebrand

The operation of dams for generation of electricity may result in fluctuations in water level in both the reservoir and the river below the dam. Such fluctuations can affect the biological, physical, and chemical components of aquatic environments. We discuss our review of available literature on the nature and significance of water level fluctuation impacts, and present a methodology for predicting loss of aquatic habitat in reservoirs due to changes in water level.

Both the amplitude and frequency of water level fluctuation affect the nature of biological impacts. We discuss two cases: 1) amplitude of fluctuation is less than 30 cm, frequency is less than 24 hours, and 2) amplitude of fluctuation is several meters, frequency ranges from days to months. The most profound potential adverse impacts are projected to occur in the littoral or shore zone of a reservoir. Decrease in water depth or dessication of reservoir bottom could result in a decrease in primary and secondary biological production and loss of fish spawning habitat and nursery areas.

The primary physical effects of water level fluctuations are expected to involve bank and bed stability and water quality. Potential effects include: 1) resuspension and redistribution of bank and bed soils within the new shore zone defined by the fluctuations, 2) leaching of nutrients and deleterious substances from shore zones, 3) changes in sediment and solute retention and water quality in the reservoir as a result of changes in hydraulic efficiency, and 4) alteration of the development and persistence of thermal stratification and resultant water quality changes.

Mitigation of adverse biological impacts may require carefully coordinated reservoir operation schedules. The preliminary assessment of the potential physico-chemical impacts of small-scale hydroelectric redevelopment suggests that not all are necessarily detrimental to the environment, and most biological and physico-chemical impacts are not beyond reasonable mitigation. Site characteristics primarily determine the significance of all impacts.

ABOUT THE AUTHORS: Dr. Szluha (Ph.D. Limnology, Michigan State Univ.), Dr. Loar (Ph.D. Zoology, Univ. of Wyoming), Dr. Turner (Ph.D. Oceanography, Florida State Univ.), and Dr. Hildebrand (Ph.D. Fisheries, the Univ. of Michigan) have been actively involved in environmental research and assessment of fossil, nuclear, and hydroelectric energy technologies. All four authors are employed at the Oak Ridge National Laboratory, Oak Ridge, Tennessee.

THREE-AGENCY CONTROL FOR CO-DEPENDENT HYDROELECTRIC FACILITY

Samuel E. Barnes

For over 50 years the Columbus Division of Water (DOW) has used two dams on the Scioto River to impound water for the City's municipal water needs. Both dams were originally designed by far-sighted early 20th century planners with provisions for the eventual installation of hydroelectric machinery. Now, it seems, the time has come to implement their dreams.

Getting the power from the dams to the Dublin Road Water Plant (DRWP), which purifies the water impounded by the dams, and providing plant energy back-up, however, presents some distribution and control problems with unusually interesting concepts. Three independent agencies are involved, and superficially it appears that each has paramount motives and a primary mandate for direct control of the generating facilities. For example:

A. Div. of Water varies water output at the DRWP to meet demand. Plant operating personnel, therefore, must have some means of controlling flow of water through the dams. Because potable water use is the primary function of the two reservoirs, DOW operations personnel must maintain "over-ride" control of hydroelectric operations.

B. Div. of Electricity routinely provides all electrical power required by the plant. Normal load, 2,000 to 4,000 kVA, is provided via redundant lines from their main switchyard. For load dispatching and system management, it is essential that DOE personnel have access to a man-machine interface controller of the hydroelectric generation facility.

C. C&SOE (Columbus & Southern Ohio Electric Co.) has a well-developed local power grid, and will "wheel" power to the DOE. C&SOE does not require control capability of the hydroelectric generators. However, schedules, forecasts, and status reports available on the CRT would be invaluable.

Control System will utilize direct digital control of generators and switchgear. It will be a distributed system in that a host computer, located at the Dublin Road Water Plant, will be the boss of five satellites—three of which will be graphic generators for CRT displays at DRWP, DOE, and C&SOE. Two satellites will perform DDC at the dam sites.

ABOUT THE AUTHOR: Mr. Barnes has a B.S.M.E. from the Univ. of Cincinnati. His professional specialty is control systems. At the Columbus Division of Water, Columbus, Ohio, he is currently Manager of Technical Services Group, which is responsible for forecasting, resources managment studies, and systems engineering.

Session Sixteen

PLANNING, INFORMATION AND METHODS

Topic: Planning for Development II

Chairman: John S. Gladwell
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University of Idaho
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PLANNING SMALL-SCALE HYDROPOWER ADDITIONS

Darryl W. Davis

Small-scale hydropower development is receiving significant renewed attention as one of our underdeveloped national energy resources. Public institutions and private organizations have begun examining the potential that exists at many reservoir sites not presently producing power. The Hydrologic Engineering Center of the Corps of Engineers has prepared a manual that provides guidance in the study of the feasibility of adding small hydroelectric power features to existing facilities. The manual preparation is sponsored by the U.S. Department of Energy through the Corps' Institute for Water Resources. The manual is designed for use by government agencies, public and private utilities, and private investors. The thesis of this effort is that a soundly prepared manual made available to private and public organizations will aid in the rapid study and implementation of promising projects. The focus is upon the technology, concepts, and economic and financial issues unique to small-scale hyropower additions.

The manual is composed of six volumes: Volume I—"Technical Guide" overviews the investigation process, provides implementation guidance, and documents case study applications; Volume II—"Economic and Financial Analysis" includes criteria and procedures for marketing and valuing power output, determining economic feasibility, and for analyzing financial requirements and issues critical to implementation; Volume III—"Hydrologic Studies" describes investigations necessary to evaluate the hydrologic integrity of the dam and estimate the power output of plant additions; Volume IV—"Existing Facility Integrity" provides guidance for assessing the ability of a site to safely accommodate a power addition; Volume V—"Electromechanical Equipment" describes selection criteria and performance characteristics of small-hydro generation and ancillary equipment; and Volume VI—"Civil Features" provides design and cost guidelines for the civil features of power additions.

The manual does include data and discussions on the topical subjects of cost escalation in economic and financial analysis, feature component selection for reconnaissance and feasibility levels of study, and time, costs, and resources required to perform the investigations.

This paper presents an overview of the manual and discusses significant findings and conclusions of studies that were performed to support preparations of the manual.

ABOUT THE AUTHOR: Mr. Davis directs activities at the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California, in the development and servicing of analytical techniques for use in Corps planning. He holds an M.S. degree in Civil Engineering from Stanford University and is a Registered Professional Engineer in California.

MARKETABILITY OF LOW-HEAD HYDROPOWER

Stephen T. Lee, G. Paul Grimsrud, Man-Loong Chan, Eric Marsh, Glenn H. Masters, J. Randall Threadgill and Abner Watts

This paper presents results from a project sponsored by the Water and Power Resources Service (formerly the Bureau of Reclamation) and the U.S. Department of Energy on the marketability of low-head hydropower in the United States.

From Phase I, four geographically-dispersed regions were selected out of twelve regions comprising the contiguous U.S. These four regions were: California, New England Power Pool, Mid-Continent Area Reliability Coordination Agreement Region, and Southeastern Electric Reliability Council.

In Phase II, representative small hydro sites were evaluated in detail with the use of a computer program called PUPS (Planning of Unconventional Power Supply) which developed optimal generation expansion plans for the market areas. Two types of generation-expansion plans were produced: a base-case plan without low-head hydropower, and a plan with low-head hydropower inserted into the market area. By comparing these cases, the market value based on generation-displacement was determined for each representative hydro site in its market area. This approach considered both energy and capacity values.

Supplemental analyses on spinning reserve and transmission and distribution credits were conducted, as well as sensitivity analyses of fuel cost escalation and interest rate.

ABOUT THE AUTHORS: Dr. Lee directed the Systems Control, Inc. project team consisting of Mr. Grimsrud, Dr. Chan, and Mr. Marsh. At Systems Control, Inc., Dr. Lee is the Director of Advanced Development and Manager of Utility and Energy Systems Planning in the Energy Systems Division. He received the B.S., M.S. and Ph.D. degrees from M.I.T. Mr. Masters was the project coordinator at the Water and Power Resources Service (formerly the Bureau of Reclamation) Mr. Threadgill and Mr. Watts, also from the WPRS, were the other members of the review panel. Mr. Masters is Regional Economist in the Division of Planning Coordination, System Control, Inc., and is located at Palo Alto, California. Engineering and Research Center, Denver Federal Center, is located at Denver, Colorado.

SMALL-SCALE HYDROELECTRIC POWER: HOW NEW HAMPSHIRE IS MAKING IT HAPPEN

Louis Klotz, Fred Manasse, and David Master

This paper discusses the extensive small-hydro resource of the State of New Hampshire and the efforts which have been made by citizens, politicians, and professionals in the State to bring such resources on line.

Recently developed statistics on dams from a major New England River Basins Commission will be examined in light of likely economic, environmental, and multiple-use constraints. Technical design measures and institutional relationships which may help reduce problems in development will be discussed. A unique attempt to cooperatively harness an entire river basin by the Salmon Falls Hydropower Association schemes to integrate small-hydro technology with other renewable resource technologies developed by the Integrated Energy Systems Division of the University of New Hampshire will be described.

Special attention will be paid to legislation and regulatory decisions which have put New Hampshire in the forefront of promoting small-hydro development. These include matters such as: utility interconnection, rate for sale of energy to utilities, wheeling of power, and direct retail sale of energy to non-utility customers.

Lastly, the paper will focus on information and technology transfer efforts which have been implemented by various universities, citizens, and industrial groups in the State to help make development a reality. In particular, major work of the University of New Hampshire, the Franklin Pierce Law Center, and Dartmouth College in the small-hydro field will be detailed.

ABOUT THE AUTHORS: Dr. Klotz received the Ph.D. in Civil Engineering from Rutgers University and was principal investigator of the Institutional Conference on Small-Scale Hydropower. Dr. Manasse received the Ph.D. from Princeton University in Physics, was co-principal investigator of the First National Hydro Conference and is Vice President of the AETA Corporation (private consulting firm). Mr. Master has a B.A. from Dartmouth College, is Staff Associate at the University of New Hampshire and is Associate Director of New Perspective, Inc. (a nonprofit research organization). All three authors have conducted extensive study efforts in the small-scale hydro field.

OPTIMIZING THE CIVIL WORKS ASPECTS OF SMALL-SCALE HYDROPOWER FEASIBILITY STUDIES

Kenneth R. Broome and Howard A. Mayo, Jr.

Equipment alternatives and costs are becoming increasingly well defined and the power generation potential of most projects can be analyzed with considerable accuracy in determining the economic feasibility of small-scale hydropower installations. The major uncertainty remaining is the cost of construction for the Civil Works items such as the intake, penstocks, powerhouse, draft tube, and tailrace, together with such other variables as rock excavation, dredging, cofferdams, and construction access.

The arrangement of the turbine-generator in a vertical or horizontal attitude, and its location (either upstream or downstream of the dam) has a significant effect on the total cost of construction. Based on the authors' work on a feasibility study for installing hydropower at Flat Rock Dam near Philadelphia, a procedure for systematically identifying potentially feasible equipment locations and configurations is described, together with a means of comparing the most likely alternatives both from an economic and an environmental standpoint.

Rather than depending on the scaling of historical costs of previous similar situations, the suggested approach tailors a solution that best fits the actual conditions of the particular site and avoids the twin problems of either overestimating costs that unnecessarily jeopardize the project's feasibility, or of underestimating them and causing subsequent financial embarrassment.

ABOUT THE AUTHORS: Mr. Broome received the B.A. and M.A. degrees in Mechanical Sciences from Cambridge University. After practicing as a Chartered Civil Engineer in London, he spent twenty years in California on the structural design and project management of various industrial projects at Gilbert Associates in Reading, Pa., is Principal Project Manager and responsible for development of the firm's capability for small-scale hydropower design.

Mr. Mayo is a graduate of Worcester Polytechnic Institute in Mechanical Engineering. His career has been devoted to the development and manufacture of hydroturbines, starting with S. Morgan Smith in York, Pa. and continuing with their successors, the Hydroturbine Division of Allis-Chalmers. He was the Sales Manager responsible for the Taum Sauk Project, the first reversible pump-turbine storage project in the U.S.A., and developed the standard design TUBE-turbine concept. He is manager, Market Development, Standard Products and Customer Service Depts., Allis Chalmers Hydro-turbine Division, York, Pennsylvania.

Session Seventeen

PLANNING, INFORMATION AND METHODS

Topic: Case Studies and Demonstration Projects II

Chairman: Farwell Smith
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THE ANNAPOLIS TIDAL POWER PILOT PROJECT

G.C. Baker, E:M. Wilson, H. Miller, R.A. Gibson, and M. Balls

The paper will state the object of the project and give general details of its location and main features, with particular reference to the generating equipment.

The method of calculating the energy yield will be explained together with the main factors influencing the result, such as the tidal regime, artificial restrictions on it, turbine blade angle, rotational speed, and submergence. Reference will be made to analagous problems in selecting these parameters in river power stations.

ABOUT THE AUTHORS: Mr. Baker is Executive Vice President, Tidal Power Corporation of Nova Scotia; Dr. Wilson is Professor of Hydraulic Engineering, University of Salford, U.K.; Mr. Miller is Straflo Project Mgr., Escher Wyss AG, Zurich; Dr. Gibson is Systems Analyst, EPD Consultants, Sidcup, U.K.; and Mr. Balls is Research Assistant, University of Salford, U.K.

CASE STUDY—ROLLINS POWER PROJECT

David C. Willer

Rollins Hydroelectric Project, 11,000 kW in size, now under construction in California, may be the premier small hydroelectric project of its kind at an existing dam that was conceived, designed and constructed as a result of the dramatic increase in energy cost after the Arab oil embargo. This plant will be generating power by the end of 1979. It is most interesting to note that the project was developed by a public district, Nevada Irrigation District, of Grass Valley, California, and, more importantly, was developed totally with private sources of funds; that is, no Federal, state or local taxes were used.

In its role as a forerunner, the Rollins Project met and overcame many obstacles, thus paving the way for projects which are now following. Included in these obstacles were numerous institutional problems such as the marketing of power and the changing of state law to permit an increase in the interest rate of public revenue bonds thus allowing the sale of taxable bonds. The physical site conditions also presented difficulties including the need to pierce a tunnel plug under an existing rock and earth fill dam to joint the reservoir to the power plant.

The most unique aspect of the project was the procurement of the advance funds, and the marketing and disposal of the power. The District, using a feasibility study as a description of costs and benefits of the project, solicited proposals from various electrical utilities in the area. Certain minimum requirements were requested in each proposal. These requirements included 1) a willingness to advance front-end money, 2) guaranteed payment of debt service, 3) guaranteed payment of operation and maintenance cost, 4) added incentive payment to the District for each kilowatt hour generated, and 5) the willingness to escalate the added incentive payment as the wholesale value of power increases. The Pacific Gas and Electric Company provided the most attractive overall offer to the District and subsequent negotiation resulted in a firm contract to sell power from the project. The cost of the Project will total $8,500,000. The cost of developing the power, assuming an average annual generation of 71.1 x 10^6 kWh, is approximately 16.5 mills per kW hour, including the 4 mill incentive payment to the District.

ABOUT THE AUTHOR: Mr. Willer received the B.S. degree in Civil Engineering from the University of Iowa and the M.S. degree from the University of Southern California. At Tudor Engineering Company he manages the water resources activities in the San Francisco office. He is responsible for the development of small and large hydroelectric projects and related water supply activities.

CASE STUDY—BROADWATER DAM POWER PROJECT

Gordon E. Little

Broadwater Dam is located on the Missouri River in Montana approximately 50 miles (80 km) southeast of Helena and is owned and operated by the State of Montana. The facility is a concrete gravity overflow dam 705 feet wide and 40 feet in height. The average annual flow is about 4,500 cfs (126 cms) with an average low flow of 2,200 cfs and an average high flow of 10,000 cfs.

Initial studies to install hydroelectric generation at this existing dam indicated that the optimum installed capacity would be about 10 MW and the average annual energy would be about 56 million kW hours.

In assessing the feasibility of the installation two alternative powerhouse configurations were studied. The first was a conventional installation located out of the river channel on the left abutment of the existing dam. The second was a configuration where the vertical turbines would be installed in a powerhouse located in the river channel on the downstream apron of the existing dam.

The unique aspect of the apron-mounted configuration was that the plant would be designed to be capable of passing the flood flows through the powerhouse. The powerhouse would otherwise cause a hydraulically undesirable constriction in the river channel and thereby a reduction in the flood passing capability. Flood passage through the plant would be possible by making the back wall of the plant removable. The configuration was model tested to investigate the power generation mode and the flood modes of operation.

The results of the feasibility studies indicate that while configurations are technically and economically feasible, the apron-mounted alternative would yield greater economic benefits. Plans are therefore underway to implement the project using this configuration.

It is thought that the unique configuration employed in the study may have wide applicability to add power-generating facilities to many existing ogee crest dams.

ABOUT THE AUTHOR: Mr. Little received the B.S. degree in Civil Engineering from the University of California at Berkeley. He has worked on a variety of hydroelectric projects in Iran, the Philippines and the United States. At Tudor Engineering Company he was responsible for the development of hydroelectric power projects in several western states and the Far East. He is Project Manager, Tudor Engineering Co., San Francisco, California.

PRELIMINARY FEASIBILITY STUDY FOR HYDROPOWER AT BRANDON ROAD LOCK AND DAM

Gerald J. Stadler and Brian Moentenich

This study was conducted by the Corps of Engineers to determine the feasibility of installing hydropower at the existing Brandon Road Lock and Dam, located in Joliet, Illinois. The existing structure is operated by the Corps of Engineers and is part of an eight-lock navigation waterway and sanitary canal connecting Lake Michigan to the Mississippi River.

At the time of construction (in the early 1930's) hydropower was considered, but never installed. However, the dam and spillway section was provided with a headgate structure so that a future powerplant could be built immediately below the dam. The proposed powerplant would use only four gates of the existing 16-gate headgate structure.

A four-unit, 15 MW tube-turbine powerplant is recommended for construction. The plant would develop about 34 feet of head and produce an average of 70,000,000 kWh annually. It is expected that the generated power would be purchased by the local utility, Commonwealth Edison Company. The construction cost would be about $11,000,000 which would result in an average power cost of 13.5 mills per kWh.

ABOUT THE AUTHORS: Mr. Stadler received the B.S. and M.S. degrees from the University of Wisconsin in Civil Engineering and is a professional engineer in Wisconsin. Mr. Stadler is in charge of all hydrologic and hydraulic activities within the Corps of Engineers, Chicago, Illinois.

Mr. Moentenich prepares specifications for procurement of hydropower turbine machinery, performs field testing of turbines and conducts transient analysis of hydropower networks. Mr. Moentenich received the B.S. and M.S. degrees from Ohio State University in Mechanical Engineering and is a professional engineer with the Hydropower Design Section, Engineering Division, Corps of Engineers, NPD, Portland, Oregon.

$\frac{\$11}{70\ \text{KWH}} = .16$

Session Eighteen

PLANNING, INFORMATION AND METHODS

Topic: Planning for Development III

Chairman: Augustine Jay Fredrich
Professor
Indiana State University, Evansville

STUDY OF FACTORS AFFECTING FEASIBILITY OF LOW-HEAD HYDROELECTRIC GENERATION

Edmond R. Bates

In recent years, many utilities and municipalities in the Northwest and elsewhere have been actively exploring the possibilities of increasing the output of their existing hydroelectric plants by replacing or supplementing existing generating units. Several factors have prompted them to take these actions. In the Northwest, especially, there has been an extremely rapid growth in the demand for electrical energy vs. thermal fuel for heating. The utilities and municipalities have also noted that there will be few, if any, additional major high-head hydroelectric sites developed, since practically all of the economically feasible and environmentally acceptable high-head dam sites are now in use. The availability of low-cost energy in the future from existing hydroelectric facilities is also in question. For example, Bonneville Power Administration is planning rate increases in the near future and has given customers a notice of insufficiency as of 1983. Alternate sources of energy (thermal) are also becoming less attractive. New nuclear projects have been plagued by spiraling costs and excessive delays. New coal-fired plants that have not been able to get underway are the Kaiparowitz plant in Utah and the Pioneer plant in Idaho. For these reasons, development of existing low-head hydro sites is being increasingly studied and often has been found to be an economical alternative to other energy sources. In addition to the economies that can be achieved, use of hydroelectric power has the additional advantages of utilizing a clean, pollution-free resource which is perpetually renewable.

The feasibility of generating electricity from hydropower developments having low heads depends on the characteristics and the cost of the available equipment as well as the cost of producing electricity from alternative sources. The recent development of the tubular turbine has resulted in many advantages for the economical development of low-head hydropower. Many units with heads as low as ten feet have been built in Europe. Twenty-five feet appears to be the practical lower limit in North America.

ABOUT THE AUTHOR: Mr. Bates received the B.S. degree from Colorado State University with graduate work at the University of Arizona, Portland State, University of Oregon, and Eastern Montana State College. During Mr. Bates' thirty-seven years of government service and six years in private practice, he has been Chief of Design and Construction for the Bureau of Land Management in Wyoming and the Portland Service Center. While in Nigeria, Africa, for U.S. AID, he worked closely with Nigerians to implement programs, plans, and design of water facilities including three reservoirs. At the Department of Energy Region VIII Office, Belmar Branch, Lakewood, Colorado, he is responsible for assessing water resource plans for energy resource development and other appropriate technology.

THE RIVER BASIN CODE AND MAPPING SYSTEM FOR HYDROPOWER SITES

Eugene A. Jarecki and Thomas F. Papsidero

A 10-digit river basin code system is developed as part of a data base management system which permits computer processing of developed and undeveloped hydropower site information. The system identifies up to 16,000 streams within the 21 Water Resources Regions of the United States in each of the principal river basins including the upstream hierarchical structure of tributary streams beginning with the main stream and ascending where appropriate to the 6th order tributary. The code system is designed to permit additional and more detailed stream coding in any area in the United States as it becomes necessary.

The labeling of streams is accomplished on a series of 85 maps (scale 1:500,000) covering the entire United States including Alaska, Hawaii, and Puerto Rico. About 5,600 locations of developed, undeveloped, and "retired" hydropower sites are being plotted on the maps with each site related to the computerized file through its River Basin Code. It is estimated that approximately 1,600 of the sites are under 15 MW in capacity.

Establishing and maintaining this river and site code system provides computer listings and analyses of hydropower data. The code and mapping system has evolved through a joint Federal effort into a user-oriented information system and is being utilized by other Federal agencies in planning studies for hydropower development.

ABOUT THE AUTHORS: Mr. Jarecki received the B.S. degree from the University of Nebraska. He worked with the Water and Power Resources Service (formerly the Bureau of Reclamation) as a Hydrologic and Investigations Engineer, and the Great Lakes Basin Commission as a Comprehensive Basin Planner. At the Federal Energy Regulatory Commission (FERC), he is responsible for the development of Hydropower Resources Assessment in the Division of River Basins.

Mr. Papsidero received the B.S. degree from the State University of New York at Buffalo. At FERC he is responsible for river basin development at the planning level with special emphasis on existing and potential hydropower applications. He worked with the Rural Electrification Administration within the Department of Agriculture, HQ, as an Environmental Engineer and with the U.S. Army Corps of Engineers, Buffalo District, as project manager for construction.

AN ENGINEERING/ECONOMIC MODEL FOR EVALUATION OF SMALL-SCALE HYDROPOWER FEASIBILITY

Dilip R. Limaye, Thomas Hough and William Meroney

This paper describes the development and application of an evaluation model for assessing the feasibility of small-scale hydropower sites. A comprehensive evaluation framework has been developed to analyze the technical, economic, institutional, regulatory and environmental aspects of small-scale hydro. The model assesses each of these considerations and provides an integrated evaluation.

The engineering submodel can examine alternative technical configurations for power generation, based on data regarding the flow characteristics, hydraulic head, drainage area, and characteristics of the turbines. This submodel is designed to operate with minimum data (average head, mean streamflow, drainage area) for a preliminary feasibility evaluation, or with detailed data regarding monthly flow duration curves, engineering characteristics and performance curves of the turbines. The output of this submodel is power output (kWh) and capacity (kW) for the optimum configuration.

The cost submodel calculates and reports cost by major classification as required in the FERC license application. The institutional and environmental submodels calculate the appropriate costs of satisfying the relevant regulations and their impacts on performance characteristics and economics.

The economic submodel calculates the relevant project revenues and costs (both fixed and variable). It also calculates the costs of the alternatives and the "breakeven point" at which the cost of the hydropower will be lower than these alternatives. A levelized annual cost is also calculated. The financial submodel examines alternative financing schemes and develops pro-forma financial reports.

The model can be used for a pre-feasibility study, feasibility study or for assistance in preparing the license application. The paper includes a description of the model and each submodel, and several illustrative examples of its application.

ABOUT THE AUTHORS: Mr. Limaye is President, Synergic Resources Corporation, One Bala-Cynwyd Plaza, Suite 434, Bala-Cynwyd, Pennsylvania. Mr. Hough and Mr. Meroney are engineers with the firm.

SUPPORT SERVICES FOR SMALL HYDROELECTRIC PROJECTS IN NORTH CAROLINA

John L. Warren

Through its Energy Institute, North Carolina has provided for support services for public and private developers of small hydroelectric projects. These services have included: 1) a survey of existing dams, 2) an analysis of institutional and regulatory factors influencing development, and 3) provision of reconnaissance-level analyses of potential sites.

Utilizing key data sources, e.g., U.S. Geological Survey data, U.S. Army Corps of Engineer surveys, and dam safety files, an inventory of those dams with the best development potential was prepared. Criteria for selecting these dams included ownership pattern, stream flow, available head, potential available power, and marketability of that power. Contact with owners of these dams is being made to encourage development where feasible.

Institutional and regulatory factors impacting small hydro development in North Carolina were examined from the following state perspectives: 1) water quality, 2) water quantity, 3) archaeological and historical resources, 4) the State utilities commission, 5) wildlife resources, and 6) dam safety. Federal perspectives examined included those of the Federal Energy Regulatory Commission (FERC), the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency.

Utilizing information developed by these earlier tasks, services are being provided to small hydroelectric developers in the following areas: 1) a clearinghouse for information on small hydro and its impacts, 2) newsletters and informal reports, 3) assistance in preparing DOE and FERC, and 4) reconaissance surveys, which assist a dam developer in determining whether detailed feasibility studies should be carried out.

ABOUT THE AUTHOR: Mr. Warren, an environmental consultant, received the B.S. degree from Davidson College, an M.F. from N.C. State University, and is currently completing the M.B.A. at Duke University. He is project leader for the 1) North Carolina Energy Institute's Small Hydro Support Project, which is being conducted by the Research Triangle Institute, and 2) a hydroelectric power feasibility study for the N.C. Department of Administration.

Session Twenty-Two

Topic: New Techniques and

Projects

Chairman: James. R. Hanchey
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POTENTIAL HYDROELECTRIC POWER DEVELOPMENT FOR VERTICAL TURBINE-SPILLWAY COMBINE

W.Y. Chow and A.B. Rudavsky

This paper will discuss the design, investigations, and development of the vertical low-head turbine-spillway combine structure located at Broadwater Dam in Montana. The objective of the Hydro Research Science (HRS) model study was the determination of the feasibility and hydraulic performance of the conversion structure. Investigations involved in this study included the following:

1. Examination of hydraulic characteristics of the power bay during the flood mode;
2. Determination of hydraulic performance of the combine structure during the generating mode and combined mode;
3. Elimination of the scour problem in the area immediately downstream of the dam during operation of generation, combined, and flood modes;
4. Determination of the appropriate flow capacity of the vertical turbine;
5. Determination of the safe range of water surface elevations for turbine operation; and
6. Optimization of the proposed design.

As a result of the model investigation, the following conclusions were reached regarding the Broadwater project:

1. The proposed design, with some modifications, was found satisfactory for the designed flow conditons (no vortexing or adverse eddying patterns were present).
2. Flow conditions under the flood mode displayed a typical submerged hydraulic jump under high tailwater conditions; therefore, scour could occur. Further studies were recommended.
3. A special shaping or protective cover arrangement for the turbine intake should be investigated and seriously discussed with the turbine manufacturer.

ABOUT THE AUTHORS: Mr. Chow received a B.S. in Hydraulic Engineering from Cheng Kung University, Taiwan, and an M.S. in Civil Engineering from Texas A&M. He is Chief Engineer, Hydro Research Science, Santa Clara, California.

Dr. Rudavsky received the doctorate degree from the Franzius Institute Technical University in Hannover, Germany. He is the Founder and President of Hydro Research Science, an applied research laboratory doing hydraulic modeling studies in Santa Clara, California.

SMALL-SCALE HYDRO SIMULATION PROGRAM

J.J. Mankauskas, Jr. and E.S. Wright

This paper describes a program which was developed to simulate operation of a low-head hydroelectric energy generation system. Because of the site-specific nature of hydro installations, many of the program parameters are characteristic of the site being simulated; e.g., time-varying characteristics of the hydro resources and user demands, and performance parameters for installed equipment. In the simulation, a controller effects the basic operating strategy, which is to maintain reservoir surface elevation between prescribed limits and maintain downstream flow above a prescribed minimum, while satisfying user demands and purchasing or selling power in energy-shortage or energy-excess situations. An important function of the program is calculation of system economics in terms of operating and investment costs. The net present value of the required system investment is calculated for future years and a comparison is made with the alternative of purchasing all power from the utility. Sample calculations are provided for proposed development of a site on the Weweantic River in Wareham, Massachusetts.

ABOUT THE AUTHORS: Mr. Mankauskas received the B.S. and M.S. from the University of Connecticut. He is presently engaged in the analysis, modeling and development of simulation programs for low-head hydro-electric generation and wind energy conversion systems with United Technologies Research Center.

Mr. Wright received the B.S. from the Air Force Institute of Technology and M.S. from Princeton University. At the United Technologies Research Center, Mr. Wright is Program Manager of UTRC's low-head hydro systems evaluations. United Technologies Research Center is located at East Hartford, Connecticut.

SMALL-SCALE HYDROELECTRIC GENERATION AND THE SALT RIVER PROJECT

Eugene J. Lauerman

To understand the Salt River Project's (SRP) commitment to small-scale hydroelectric generation, it is necessary to understand SRP's position within the central Arizona community. SRP supplies electric power to about 290,000 residential, industrial, commercial and agricultural customers. In addition, SRP supplies water to approximately 260,000 acres, 119,000 of which are agricultural in nature. The water system is comprised of six reservoirs, 248 deep-well pumps and over 1,200 miles of canals, laterals and ditches. Small-scale hydroelectric plants attempted by SRP will use these canals as prime waterways.

Small-scale hydroelectric generation has been in use at SRP since 1897, when records indicate a small power plant went into service. That plant was joined by three others, one of which is still in use. SRP is now rebuilding one of the other three as a DOE demonstration project on the South Consolidated Canal. It is scheduled to go on-line in 1981.

The reason for retiring the three small-scale 25-Hz hydro stations was economic. When the changeover to 60-Hz generation was begun in 1949, fossil fuels were inexpensive and refurbishing the sites was economically unfeasible. A 1974 study showed the benefit cost-ratio of less than one. Since then, the cost of fuel has risen to a point where the benefit cost-ratio, in 1978 dollars, is 1.41 to one.

Originally, power supplied by SRP was totally 25-Hz hydroelectric at four storage dams in addition to the small-scale systems. As power needs grew, SRP began using natural gas and fuel oil. Today the bulk of the power provided by SRP is coal-generated but with dependence on fuel oil for some generation. Small-scale hydroelectric generation will be used to help offset some of the fuel-oil firing.

Considerations by SRP for small-scale hydro projects include: head; flow records/flow duration; physical setting; equipment selection; economic feasibility; and environmental effects.

ABOUT THE AUTHOR: Mr. Lauerman received the B.S.E.E. from the University of Arizona. He is a graduate of the Industrial Management Institute at Arizona State University and also the Power Systems Engineering Course offered by GE. He is responsible for the corporate functions of research and development and for future generating resources studies and related capital cost estimates. He also provides project manager services for start of new power projects and consulting services on power generation projects, and is Manager, Research and Future Project Studies, Salt River Project, Phoenix, Arizona.

WEED HYDROELECTRIC DEVELOPMENT— A SMALL-HYDRO CASE HISTORY

James D. Calvert, Jr.

This paper describes a small hydroelectric development of 630 kW successfully undertaken by the Village of Gresham, Wisconsin in the mid-1960's. Built at a time when many small hydros were being routinely abandoned as uneconomical, the Weed Hydro Development attests to the sound wisdom of developing our renewable energy resources and realization of the long-term benefits therefrom.

It may be concluded from the experience with this small-hydro development that as size of installation decreases the problems commonly associated therewith do not decrease in a proportional manner.

Furthermore, for small hydros local leadership and sponsoring organization strength is very important. Often a single individual is the key leader responsible for achieving success on his own strengths, contacts, and perseverance. Where the sponsoring organization is an existing utility, this matter of local support is more easily attained.

Cost controls on small hydros are vitally important and if not properly managed can seriously jeopardize economic viability.

Finally, it should be recognized that engineers and contractors often employed on small hydros have limited experience and capabilities and great care must be taken to assure that they are well organized and financed and clearly understand their job.

In retrospect, the economic lesson to be learned from this experience is that what appears to be a marginal or near marginal hydro undertaking based on short- term energy costs, will nearly always turn out to show substantial savings over the long haul. This is particularly true today and for the foreseeable future where costs of alternative fossil fuels are escalating at a rapid rate.

ABOUT THE AUTHOR: Mr. Calvert is an Executive Consultant with Gilbert/Commonwealth, Jackson, Michigan.

Policy Sessions

Session Five

POLICY

Topic: Public and Private Finance

Chairman: Robert M. Shepard
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POLICY RECOMMENDATIONS FOR FEDERAL AND STATE GOVERNMENTS TO EASE FINANCIAL CONSTRAINTS ON LIMITED-RESOURCE HYDROPOWER DEVELOPERS

J. Keen Holland

The impact of social/environmental, legal/institutional, and economic/financial constraints on limited resource potential has not been adequately assessed. Government (Federal and state) and utilities (IOUs and public power agencies) have little experience in dealing with developers and individuals, small businesses, small municipalities, and RECs seldom have the expertise or resources to deal effectively with regulatory agencies or major utilities. It is this class of potential developers who stand most in need of assistance.

The legal/institutional barriers encountered by small projects have been addressed at the Federal level and by several of the states. Social/environmental barriers, may well be insuperable; economic/financial barriers probably can be overcome in most cases, but too little has been done on this front at either the Federal or state level.

Based upon a study of small hydropower and experience with public and private developers the following recommendations are offered.

1. State outreach and technical assistance programs should be instituted to overcome lack of money and skilled personnel available to developers and to bring information about the possibilities for small hydro development to the attention of large numbers of potential developers.
2. States should take action to streamline their license and permit procedures; they should reevaluate the public benefit of small hydro developments as public utilities and the additional tax burden which such designation often imposes.
3. Other Federal actions should include expanded residential and business tax credits and tax-free bonds.

ABOUT THE AUTHOR: Mr. Holland, an economics and environmental science graduate of the University of Virginia, has taught economics at the college level and served as a policy analyst in the Federal Government. Presently Mr. Holland is working to develop markets for the hydro power consulting capabilities of Berger Associates, Harrisburg, Pennsylvania.

MUNICIPAL FINANCING OF SMALL-SCALE HYDROPOWER

Larry Hobart

Development of small-scale hydroelectric facilities at new or existing dams is increasingly attractive to local publicly-owned electric utilities which supply power to some 2,200 communities throughout the United States. Soaring fuel prices and rising wholesale power rates enhance the economics of hydropower, which also benefits from short construction lead-time with known techniques; potential long plant life; low maintenance requirements; decreased transmission; multiple-purpose character; environmental advantages; remote control opportunities; and low outage rates.

General obligation and revenue bond financing provides the means of applying low-cost municipal borrowing to small-scale hydroelectric projects. "Joint action" efforts allow the pooling of electrical load and financial resources where a single system cannot construct or integrate a generating facility. Substitutes for conventional bond financing encompass use of retained earnings, leasing, commercial loans, and government loans and grants.

Examples of current financing activities in the field of small-scale hydropower development by public power systems include the Turlock Irrigation District, and Seattle and Tacoma, Washington (irrigation canal drops); St. Charles, Illinois (hotel facility); Carlyle, Illinois (adjacent river); Municipal Electric Authority of Georgia and Massachusetts Municipal Wholesale Electric Company (joint action); and Intermountain Consumer Power Association (leverage leasing).

ABOUT THE AUTHOR: Mr. Hobart has been a member of the staff of the American Public Power Association since 1960. His responsibilities with APPA involve legislative and power supply problem analysis for local public power systems. Mr. Hobart holds a Masters of Public Administration degree from the University of Michigan, where he was a Ford Foundation Fellow.

PUBLIC FINANCING OF SMALL-SCALE HYDROPOWER—THE MUNICIPAL GOVERNMENT PERSPECTIVE

George L. Tuttle

The City of Paterson, New Jersey (population 155,000) is the site of the "Great Falls" on the Passaic River—the second largest falls in the eastern United States after Niagara. This site was, in fact, the location of early industrial development which utilized hydropower through an elaborate raceway, or canal, system. The natural beauty and economic potential of the Great Falls area attracted the interest and support of Alexander Hamilton as early as 1791. It was only in this decade, however, that renewed interest in the importance and potential of the Great Falls has re-emerged. In 1976, President Ford designated the Great Falls area as a National Historic Landmark. And today, we are prepared to undertake a new hydroelectic project as an environmentally sound method of meeting our energy needs. In the case of Paterson, hydropower is also an integral part of our efforts to stimulate the local economy.

Therefore, my perspective is that of a municipal official seeking to find answers to the financial questions associated with hydropower development. In the paper, I shall describe the key financial questions which a unit of local government must successfully answer if it proposes to develop hydropower.

ABOUT THE AUTHOR: Mr. Tuttle is Director of Finance of the City of Paterson, having served in that capacity for five years. He previously was Comptroller of the N.J. Housing Finance Agency. He is a graduate of Drew University (B.A. cum laude Economics 1968) and has completed numerous courses concerning municipal bonds and public finance.

Session Six

POLICY

Topic: Water—Management and Use

Chairman: Dr. Lewis H. Blakey
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DEVELOPMENT OF A SMALL-SCALE HYDROELECTRIC PROJECT: POLICY AND POLITICAL CONSIDERATIONS, BROADWATER DAM, MONTANA

Richard L. Bondy

The State of Montana owns some forty water conservation projects including twenty-three active reservoirs, all of which are managed by the Department of Natural Resources and Conservation (DNRC). These projects are generally in poor condition and are deteriorating. Revenue from the development of hydroelectric power at three of these projects is seen to be a major source of funding for needed repairs to all state-owned projects.

The first project proposed for installation of hydroelectric generators is the Broadwater Dam, a low diversion dam on the Missouri River. The proposed installed capacity of ten megawatts would produce power with a value of over $700,000 per year in excess of production costs.

Because of the pressing need for repairs to the state water projects, it is DNRC's desire to maximize revenues from the power sales. On the other hand, potential customers wish to obtain the power as inexpensively as possible. The Vigilante Electric Co-op, a potential customer for the power from the project, organized a powerful legislative lobbying effort in support of a law which would have allowed it to obtain power from the Broadwater Project at one mill above the power production costs. This law would also have prohibited powermarketing by DNRC. The proposed law passed the legislature but was vetoed by the Governor.

To date, DNRC has applied for a water right and for a preliminary FERC license for the Broadwater Project. With the help of Tudor Engineering Company and the U.S. Department of Energy, a full-scale feasibility study has been completed which provides a reliable cost estimate as well as an accurate description of project output. A power purchase contract is now being negotiated with potential customers. Using the contract as collateral, the remaining steps, which include final design, construction, and power production, can be financed.

ABOUT THE AUTHOR: Mr. Bondy, a professional engineer, received the B.S. degree in Civil Engineering from the University of Washington. As Chief, Engineering Bureau, Water Resources Division, the Montana Department of Natural Resources and Conservation, he is responsible for the State-owned water conservation projects, the hydroelectrification program, the State's dam safety program, the State's floodplain management program, and other water resources engineering assignments.

FEDERAL RESERVED WATER RIGHTS: IMPACT ON SMALL-SCALE HYDROPOWER DEVELOPMENT

Gary J. Fisher

Federal reserved water rights have been recognized by the United States Supreme Court as being created to the extent necessary to carry out the purposes for which the United States sets aside land for such things as Indian reservations, national parks, national forests, wildlife refuges, etc. Federal reserved water rights are: (1) created by implication as well as by express language; (2) arise from Federal law, and are not dependent on state law for their existence or perfection; (3) do not require that water be put to actual use; and (4) have a priority date as of establishment of the reservation. Because of these features—which are generally not recognized under the Western water law doctrine of appropriation—and the fact that the scope and extent of some reserved rights remains unclear and substantially uncoordinated with state water rights systems, the Federal reserved water right has created substantial uncertainty over the right to use water in areas with Federal reservations.

There is little hard information about the effect of Federal reserved water rights on existing and future hydropower developments. On the one hand, actual consumptive uses by the Federal Government, particularly for use on Indian reservations, could have adverse consequences on downstream hydropower developments. On the other hand, non-consumptive uses of Federally-reserved water; i.e., maintenance of instream flows for fish and wildlife, scenic, aesthetic and environmental values, may very well have the practical effect of keeping downstream turbines running in many water-scarce areas and provide the water necessary for an expanded hydropower industry. Furthermore, DOE may wish to claim—although it has not done so yet—reserved water rights specifically for hydropower development on the hundreds of power site withdrawals scattered throughout the West.

Until legal uncertainties concerning the scope of the reserved right are eliminated, and those rights are systematically identified and quantified, the actual impact on hydropower development in general, as well as in specific cases, is impossible to predict.

ABOUT THE AUTHOR: Mr. Fisher received the B.S. and J.D. degrees from the University of Wyoming and is a member of the Wyoming State Bar and the District of Columbia Bar. Mr. Fisher has been responsible for assisting in the coordination of the President's Water Policy Implementation Task Force on Federal Non-Indian Reserved Water Rights and assisted in drafting a recent Solicitor's Opinion on Federal Water Rights. He is a Special Assistant to the Associate Solicitor for Energy and Resources, U.S. Department of the Interior, Washington, D.C.

PROCEDURES FOR EVALUATING NATIONAL ECONOMIC DEVELOPMENT (NED) BENEFITS FROM FEDERAL SMALL-SCALE HYDROPOWER PROJECTS

James F. Johnson

On July 12, 1978, President Carter directed the Water Resources Council to modify the Principles and Standards for Planning Water and Related Land Resources in order to integrate water conservation into project and program planning and review, and to require preparation of a primarily nonstructural plan whenever a structural project or program is considered. In addition, the President directed the Council to carry out a thorough evaluation of current agency practices and to publish a planning manual to ensure that benefits and costs are estimated using the best current techniques, and calculated accurately, consistently, and in compliance with the Principles and Standards and other applicable economic evaluation requirements.

In response to this direction, the Water Resources Council established a Task Force to revise the Principles and Standards and to develop economic evaluation procedures, including the evaluation of national economic development benefits from hydropower. This effort was initiated in August, 1978 and is nearing completion. The proposed final procedures have been submitted from the staff to the Agency Members of the Water Resources Council for approval.

The proposed procedures provide significant changes in the way that hydropower projects are evaluated. These changes are discussed, especially as they relate to small-scale hydropower development.

ABOUT THE AUTHOR: Dr. Johnson received the Ph.D in Economic Geography from the University of Chicago in 1970, specializing in water resources management. Prior to his assignment as Principles and Standards Task Force Leader, at the Water Resources Council, Washington, D.C., Dr. Johnson was planning division coordinator for the National Hydropower Study and other special hydropower activities in the Office of the Chief of Engineers, Washington, D.C.

NATIONAL HYDROELECTRIC POWER STUDY; A ROLE FOR HYDROPOWER AS A FUTURE ENERGY RESOURCE

James R. Hanchey

With all the concerns for the development of new energy resources to alleviate the national energy shortage, people often overlook the potential contribution of hydropower. Hydropower provides about 14 percent of the national total electrical generation capability with an installed capacity of about 71,000 MW and an average annual energy generation of about 250 billion kWh/year.

Over the past two decades the potential for available hydropower generation has been largely discounted. Most of the more promising sites have been developed. Another important factor is initial capital costs which have placed hydropower at an economic disadvantage with respect to thermal generating stations, during a period of low fossil fuel prices.

Following two studies by the Corps of Engineers in 1974, Congress authorized a National Hydroelectric Power Study (NHS) in 1976 with the objective of providing an assessment of hydropower potential in the U.S. The NHS is made up of three basic parts—the first is directed toward developing a comprehensive inventory of potential at both existing dams and undeveloped sites, the second is an estimate of the potential for present and future development of additional hydroelectric generation, and the third is an identification of policy, and technical issues which might affect the realization of this potential. Completion of the NHS will provide a framework to recommend new hydropower development programs.

This paper will describe the study approach, discuss preliminary results of the inventory of hydropower potential, provide an overall assessment of the contribution that hydroelectric power could play in meeting energy needs, and discuss the significant issues associated with a national program to develop additional capability at existing dams and undeveloped sites in various regions of the U.S.

ABOUT THE AUTHOR: Mr. Hanchey is presently Acting Director of the Corps of Engineers Institute for Water Resources. Prior to this assignment he served as Study Manager for the National Hydropower Study and Deputy Director for Special Studies at IWR. Mr. Hanchey received the B.S. in Civil Engineering from the University of Southwestern Louisiana, the M.S. in Civil Engineering from Tulane University and has completed an additional two years of graduate work in water resources planning at Stanford University.

Session Thirteen

POLICY

Topic: Environmental Issues and Impacts

Chairman: Peter Henault
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POSSIBLE IMPACTS OF HYDROELECTRIC DEVELOPMENTS ON FISH AND WILDLIFE

Alfred W. Eipper

On exisiting dams, the additional impacts produced by installing hydroelectric generating facilities can be classified in two groups, according to the mode of operating the powerplant. Likely impacts from plants operated on a run-of-river basis are turbine-induced mortality and injuries to down-migrating fish, impingement at turbine intake trash racks, and siltation and release of toxicants in sediments from plant construction and from any required dredging of the old impoundment. Water-level fluctuations from hydroelectric plants operated in a store-and-release manner on existing dams usually produce such additional impacts as water warming, bank slumping, decreased spawning and food production and degradation of wetland habitats above the dam; with bank erosion, bottom scouring, loss of cover and food, and flow regulation with periodic flow shortages dominating the potential downstream fisheries impacts. Another important point to bear in mind when considering impacts at existing dams is that the installation of a generating facility may of itself increase the permanence of a dam substantially, by expanding the dam's utility and the capital investment it represents.

Impacts typically associated with newly-constructed hydroelectric dams include those mentioned above, plus creation of a reservoir habitat with changes in water quality and species composition of aquatic organisms, and loss of stream and terrestrial habitats and spawning sites above the dam; upstream and downstream migration blockage and (occasionally) embolism in fish below the dam. More detailed treatments of hydropower impacts on fish and wildlife resources are given in the Service's Hydroelectric Power Project Review Manual and other reference sources cited therein.

Cumulative impacts from a series of dams in the same river system are a special concern in those New England rivers that are involved in the joint Federal-State Anadromous Fish Restoration Program. Fish passage facilities may be needed at many of the dams on such streams.

ABOUT THE AUTHOR: Dr. Eipper received a B.S. degree in Wildlife Conservation from the University of Maine and a Ph.D. in Fishery Biology from Cornell University. At Cornell from 1953 to 1975, he was engaged in teaching, research, and publication in the areas of ecology and management of fishery resources. In his present capacity, as Northeast Power Plant Activities Leader—U.S. Fish and Wildlife Service, Newton Corner, Massachusetts, he is concerned with decision-making, siting, and operation of powerplants to minimize impacts on populations and habitats of fish and wildlife.

THE DEPARTMENT OF ENERGY ENVIRONMENTAL SUBPROGRAM PLAN FOR SMALL HYDROELECTRIC DEVELOPMENT

Stephen G. Hildebrand and George B. Grimes, Jr.

The primary objective of the U.S. Department of Energy's (DOE) Small Hydroelectric Power Development Program is to encourage and accelerate development of exisiting dams with a potential generating capacity of 15 MW or less. The DOE Environmental Subprogram Plan is intended to provide necessary investigations to ensure small hydroelectric technology is developed in an environmentally acceptable manner. These investigations should identify potential environmental constraints and benefits that will have to be factored in, with engineering and economic concerns, for overall technology assessment. We present here an overview of the rationale, approach, and progress to date of efforts in support of the DOE Environmental Subprogram Plan.

The DOE Environmental Subprogram Plan is a phased approach to identification and analysis of environmental issues. Phase 1 of the plan includes in-depth analysis (based on available literature) of potential environmental issues already identified (fish passage, water level fluctuation, dredging, and turbine mortality of aquatic biota). Phase 2 includes analysis of existing water quality data at small dam systems in the United States to identify potential issues, and the initiation of specific environmental studies at DOE small hydro demonstration sites. The final phase of the program will include necessary research on major outstanding environmental issues that cannot be resolved through phases 1 and 2.

Phase 1 of this effort is complete and general results are described. A major problem in this phase has been the relative lack of existing information specific to small hydroelectric systems, compared to the extensive literature available for large-scale hydroelectric sites. Phase 2 and phase 3 are ongoing activities and current status of these tasks is summarized.

ABOUT THE AUTHORS: Dr. Hildebrand received the B.S. from Wabash College, and the M.S. and the Ph.D. (Fisheries) from the University of Michigan. He has been involved with environmental research and assessment related to fossil and nuclear fuel cycles and hydroelectric power development. He is a Research Staff Member, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Mr. Grimes received the B.S. degree in Chemical Engineering from Rice University and the M.S. degree in Instrumental Science and Physics from the University of Arkansas. Mr. Grimes, as Staff Engineer, U.S. Department of Energy, is responsible for engineering, demonstrations, and environmental aspects of small hydroelectric applications.

LAND USE AND SMALL-SCALE HYDROPOWER: AN OVERVIEW OF ENVIRONMENTAL IMPACTS AND INSTITUTIONAL RESPONSES

Reuben C. Plantico

The potential contribution of small-scale hydropower to the Nation's energy base has generated considerable enthusiasm within the public and private sectors. One alleged advantage of small-scale hydropower is that it is an environmentally "safe" form of energy production. While some assessments tend to support this assertion, some uncertainty about the actual and potential environmental impacts of small-scale hydroelectric generation remains.

One aspect of environmental planning for small-scale hydropower concerns impacts on land use—particularly at the land/water interface. Environmental impacts include those related to facility citing and construction, upstream and downstream effects on riparian areas (including floodplains and wetlands), transmission line location and the indirect impacts of recreational and economic activity. Decisionmakers ought to be aware of the potential effect of these impacts on fish and wildlife habitat, water quality, and other valuable natural systems.

Several institutional mechanisms exist for the consideration of land-related impacts of small-scale hydropower. Relevant Federal, state and local agencies can give consideration to such impacts during planning and decisionmaking processes.

ABOUT THE AUTHOR: Mr. Plantico received a B.A. degree from Lawrence University, a M.A. from the University of Wisconsin-Madison, and a J.D. from the Lewis and Clark Law School. He has written articles in the areas of land use planning, water law, and constitutional law. He is Legal and Institutional Affairs Specialist—U.S. Fish and Wildlife Service (OBS), National Water Resources Analysis Group/Eastern Energy and Land Use Team, Kearneysville, West Virginia.

RECENT CONGRESSIONAL ACTIONS AFFECTING SMALL-SCALE HYDROPOWER

Sarah Glazer

In 1978, Congress passed legislation providing Federal loans for feasibility studies and construction of small hydropower facilities up to 15 megawatts at existing dams.

There will be several attempts at this session of Congress to expand the legislation to include construction projects at new sites and to enlarge the definition of small hydro projects to 25 megawatts.

Environmentalists generally regarded the 1978 National Energy Act's provisions favorably since they were limited to existing dam sites only. But the prospect of encouraging new hydropower construction—as proposed in legislation by Senators Gravel (D-Alaska) and Jackson (D-Washington) is causing concern in the environmental community. Environmental groups are concerned that new small hydro projects could cause the same environmental problems—such as disturbing wildlife—that have characterized large hydro projects although on a smaller scale.

Congress this year has showed that it is anxious to encourage domestic energy production even at the expense of the environment, suggesting it will look favorably on efforts to encourage new small hydro development. House sponsors of the 1978 legislation are likely to fight those efforts, however.

ABOUT THE AUTHOR: Ms. Glazer is a staff writer on energy issues for the Environmental Study Conference, a bi-partisan congressional group that tracks legislation for its 300 members of the House and Senate. She is staff writer, Environmental Study Conference, 3334 House Office Building Annex 2, Washington, D.C.

Session Fourteen

POLICY

Topic: Energy

Chairman: Dr. Allan Hirsch
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AN ANALYSIS OF INSTITUTIONAL, ECONOMIC AND ENVIRONMENTAL RESTRAINTS ON HYDROELECTRIC DEVELOPMENT OF EXISTING DAMS

Robert J. Taylor

The Johns Hopkins University Applied Physics Laboratory has developed for the Department of Energy a methodology which helps quantify the impact of the institutional, economic, and environmental (IEE) restraints on the hydroelectric development of existing dams. The methodology involves determination of the incremental costs of hydroelectric generation versus the potential hydroelectric energy output within a designated area. The resulting hydroelectric energy supply curve (kWh versus ¢/kWh) is a valuable tool for assisting in determining what governmental policies will encourage greatest development of the resource. The following are some of the questions this tool should help answer: What are the types of hydroelectric developers that should be encouraged and how should this be done? What is the effect of taxes and insurance on the supply? What effects do the present licensing costs have upon the supply? What is the effect of low-cost turbine-generators on the supply? What are the impacts of the present environmental and recreational requirements? What would be the effect of governmental subsidies, loans, and assistance on the hydroelectric supply?

The methodology has been applied to the area of Pennsylvania, Maryland, and New Jersey. Three hundred and ninety-three dams were identified with individual potential capacities greater than 50 kW. At a price of 40 mills/kWh the potential capacity estimate was 320,000 kW with an annual energy potential of 1.7×10^9 kWh.

The type of developer was found to have significant effect on the potential supply. The reason for this is the difference in the annual fixed charge rate expected for private versus public developers. At a price of 25 mills/kWh, the estimated supply potential from public developers (annual fixed charge rate of 10.4%) is almost four times the estimated supply potential from private developers (annual fixed charge rate of 17.9%). Low cost loans (6.875%) for private developers and a 50% reduction in taxes would allow private developers to supply, however, 85% of the potential available from public developers.

The effect of licensing costs on the supply appears to be almost insignificant. However, cost reductions in the turbine-generator equipment and powerhouse can substantially increase the supply. For example, a 30% cost reduction increases the supply by almost 80% at a price of electricity to the developer of 25 mills/kWh.

ABOUT THE AUTHOR: Dr. Taylor received the B.A. degree from the University of Utah and the Ph.D. degree from Cornell University. As Senior Staff Physicist, at the Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland, he is involved in several energy related projects.

PRIVATE FINANCING OF SMALL-SCALE HYDROELECTRIC PROJECTS

Hugh W. McLeod

Small-scale hydroelectric power projects represent an increasingly important source of energy. The paper is an outline of key elements in project financing designed to assist those companies and individuals who seek opportunities in this field, or know of opportunities that need further development.

The sharp acceleration in the cost of oil and coal since the Arab oil embargo combined with a desire on the part of government and utilities to promote small-scale hydroelectric projects, has generated a great deal of interest in hydropower. Many projects which were not economical or practical several years ago can now be undertaken on a profitable basis for both the developer and power purchaser. The result is that small-scale hydroelectric projects are becoming a very exciting and dynamic area. The outlook is for continued rapid growth in this emerging industry. In Europe, a traditionally high-cost energy area, the small-scale hydro technology itself is well known. This is transferable to the U.S. but the domestic technology of financing these projects is in the process of being developed and is not well understood or standardized.

ABOUT THE AUTHOR: Mr. McLeod holds the M.B.A. degree from Harvard School of Business. He is Head of the Utility Lending Group and the Project Finance Group and Vice President of the New England Merchants National Bank, Boston, Massachusetts.

1 mill = $.001

ELECTRICITY GENERATION ON RURAL AREAS— A FUTURE FOR SMALL-SCALE HYDRO

William B. Telaar

The Rural Electrification Administration (REA) finances over 1,000 consumer-owned rural electric cooperatives, most of which purchase wholesale electric energy from investor-owned utilities, Federal and state-owned power agencies or from generation and transmission cooperatives. Some distribution cooperatives own small generating stations, most of which use scarce and expensive oil and natural gas. These rural electric utilities own about half of the rural powerlines in the nation, serving about half of rural America. There are thousands of potential small hydroelectric sites in the rural areas which could supply a substantial amount of supplemental electric energy to the cooperatives. The cooperatively-owned network of lines can distribute the energy to where it will be needed and can supply necessary backup power to the consumer-owned small hydro installations. Private developers may provide a portion of their own electrical requirements and possibly derive some profit from the sale of surplus energy.

To encourage development of the resource and to insure continued long-term use and acceptance, we must begin with fair relationships with all parties and proceed on a sound technical, financial, and organizational basis. Costs must be kept to a minimum, commensurate with satisfactory construction and operation. For utility-owned units, careful planning is necessary concerning economics, as well as transportation and marketing of power and energy. Utilities which purchase power must coordinate activities with the local utility.

Private developers must generate energy with acceptable frequency, voltage and power factor, among other considerations, under safe conditions. Limitations include the necessity for generation backup to assure continuous service.

With proper understanding and coordination between the owner of the small-scale hydro installation, the local electric utility, and the power supply entity, small-scale hydro can supply significant amounts of supplemental electric energy and thereby help achieve our national goals of reducing the use of scarce and expensive fossil fuels.

ABOUT THE AUTHOR: Mr. Telaar holds a B.S. degree from the University of Arkansas and is a registered professional engineer. His experience with the electric utility industry includes working with distribution lines and substations, transmission lines, and generating stations, mostly with the Rural Electrification Administration. For the last five years he has held the position of Energy Resources Engineer with REA, Department of Agriculture, Washington, D.C.

THE SOCIAL IMPLICATIONS OF HYDROELECTRIC ENERGY

John A. Waring

In North American industry, 99% of the work is performed by technological energy—man-hours are microscopic trivia. In our agriculture the amount of toil is likewise barely detectable, less than 1%—in transportation and communications, it is even lower, i.e. technological energy comes even closer to being 100% technological.

This is exactly the reverse of the 6,000 years of toil and scarcity without technological energy, when economics and politics were in their prime manipulating millions of people to do virtually all the work, produce what little was made, and to buy and sell the scarce values with tokens of price and barter.

In diametric contrast, a continuous accounting of energy will be the first step toward a dynamic balance between technology and our metallurgic and agrobiologic resources, between our industrial capacity to produce an optimum abundance and human needs—material and cultural.

When this is done, on a functional, interdisciplinary basis, an entirely unprecedented energy society will come to scientific and artistic fruition.

The energy implications are intriguing—not utopian philosophy or ideology, but technically feasible reality. For example, the basic concept for a continental hydrology has been completed: coordinating the construction and operation of all rivers, lakes, and canals from Coast to Coast, combining large and small hydropower and tidalpower for marine train waterway transportation, flood control, irrigation, and recreation. The power transmitted underground up to 3,000 miles by 1,000,000 volt d.c. is part of a continental systems for technological-ecological governance in dynamic balance, which includes an energy-based railroad system, housing, cities and so on. The concept is derived from energy determinants, statistical mechanics, mathematical thermodynamics, and the knowledge of technology and laws of Nature.

Howard Scott (1890–January 1, 1970) the engineering scientist who discovered and developed the Energy Determinant laws, originally conceived this concept of applying science in order to build a functional civilization worthy of the scientific and artistic intelligence of mankind.

ABOUT THE AUTHOR: Mr. Waring is a research writer, lecturer, and consultant on the social, industrial, and historical impact and implications of science, technology, energy, and natural resources. He lives in Takoma Park, Maryland.

Session Twenty-Three

Topic: Problems, Economics, and Ideas

Chairman: George B. Grimes, Jr.
Hydroelectric Resources
Development Staff
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Washington, D.C. 20461

SMALL-SCALE HYDROPOWER DEVELOPMENT IN THE WEST

Alfred C. Ingersoll, Fred K. Manasse, J. Morley English, and David Master

While most attention on small-scale hydropower has focused on the potential for development in the Northeast, there are substantial opportunities and interest in small-scale hydro in the West.

No technical problems of substance were uncovered in a 3-day workshop on the subject, held July 30–August 1, 1979 in Pomona, California under the auspices of UCLA Extension and sponsorship of the Department of Energy.

The most critical barrier to small-scale hydro development in the West appears to be marketing the power produced. While New Hampshire has passed landmark legislation mandating the purchase of small-scale hydrogenerated energy by utilities, there is no such law in the West. Closely associated with marketing is the wheeling of power from point of generation to point of use.

Financing early development of small-scale hydropower requires tax advantages. Tax-free bonds, for example, are limited to energy producers who sell no more than 25 per cent of their energy to investor-owned utilities (IOU). Regulation and licensing may hinge on whether small-scale hydro can be considered a renewable resource.

Some environmental impact questions relate to point source pollution. Economic feasibility questions center on such matters as inflation, current and future price of oil, risk and discount rate, opportunity costs and shadow prices.

The Workshop concluded that although the President calls for energy to be "the moral equivalent of war," it is hard to get individuals, corporations and institutions to set aside their natural economic interests in favor of "the public good." This means that the development of small-scale hydropower will require substantial assists in the form of subsidies, tax benefits, special allowances in regulations and licensing, as is now the case in solar development.

ABOUT THE AUTHORS: Dr. Ingersoll is Director of Engineering Extension, UCLA. He holds the B.S., M.S. and Ph.D. in Civil Engineering from the University of Wisconsin.

Dr. Manasse is Professor of Electrical Engineering, University of New Hampshire. He is a graduate of CCNY and holds A.M. and Ph.D. degrees from Princeton University.

Dr. English is Professor Emeritus of Engineering and Applied Science, UCLA and holds degrees in Civil Engineering from the University of British Columbia and USC and the Ph.D. from UCLA.

Mr. Master is a consultant in energy systems and holds the B.A. degree from Dartmouth College.

PROBLEMS IN EVALUATION OF FEDERAL SMALL-HYDRO PROJECTS

Richard L. Mittlestadt

A number of institutional factors make the economic and financial evaluation of Federal small-hydro projects somewhat unique. Some of these factors in fact tend to discourage installation of powerplants at Federal projects. This paper summarizes these institutional constraints and discusses some possible solutions to the problems they create.

1. *Economic Evaluation.* How does small hydro fit conventional hydropower evaluation procedures? Does small hydro have dependable capacity and if so, how can it be measured? Is evaluation on basis of energy value alone more appropriate?

2. *Principles and Standards Manual.* How does the new Principles and Standards evaluation manual affect small hydro? Is the literal application of all facets of the proposed procedures appropriate?

3. *Marketability.* What are some of the problems involved in evaluating the marketability of power from Federal small-hydro projects?

4. *Operational Constraints.* What are some of the operational problems associated with adding small hydro to existing projects? What kind of operational modifications could improve the quality of power output? Are these modifications desirable, considering their impact on other river uses? What kind of operational limits could be imposed on the use of the hydro plant?

ABOUT THE AUTHOR: Mr. Mittelstadt received the B.S. and M.S. degrees from Oregon State University. He has been with the Corps of Engineers since 1960, with early work in the areas of hydroelectric powerhouse design and river basin planning. Since 1967 he has been involved in hydropower planning—power studies, operational planning, and economic analysis—and is currently head of the Long Range Planning Unit of North Pacific Division's Power Section. Recent work has been in development of the hydropower chapter for the Principles and Standards Manual, utilization of production cost models for power benefit evaluation, and preparation of feasibility studies for small-hydro projects in Chicago, New York, and the Pacific Northwest. He is a Hydraulic Engineer, North Pacific Division, Corps of Engineers, Portland, Oregon.

DEVELOPMENT OF SMALL HYDROELECTRIC PROJECTS IN THE COLUMBIA BASIN PROJECT, WASHINGTON

Harry P. Hosey

The Columbia Basin Project is a multi-purpose development constructed by the Water and Power Resources Service (WPRC), formerly the Bureau of Reclamation. The primary function of the project is to supply irrigation water to more than 1 million acres of irrigable land. That is an area approximately equal to the size of the State of Delaware. The source of water is Franklin D. Roosevelt Lake, formed by Grand Coulee Dam. Altogether, the irrigation system includes 330 miles of main canals, 2,000 miles of laterals and 2,200 miles of drains and wasteways. Various facilities throughout the project—dams, checks, chutes and drops—offer the potential of hydroelectric energy generation. Preliminary investigation of six potential sites indicates that more than 100 MW of installed capacity are economically and technically feasible. Also, many additional small hydro sites are available which have not been assessed at this time.

In recognition that a procedure should be established which would serve as a precedent for all of the sites, one was selected for concentrated attention. This was a 5 MW plant at a 52-foot head canal check structure. Based on a bare bones feasibility study, a power purchaser was obtained to act as the District's financial partner. The report also served to identify and resolve many of the institutional legal and technical problems associated with a project of this type. After 18 months, this project is now in the final design stages and, with the road map it provided, the remaining 95% of the project should follow in a more cost effective and schedule-streamlined manner.

This existing resource, being developed by the Columbia Basin Project Irrigation Districts, will not solve the regional energy problems, but it represents a significant source of energy which is immediately available. Construction and successful operation of the District's hydropower projects is likely to spark greater interest in construction of similar sites throughout the region.

ABOUT THE AUTHOR: Mr. Hosey received the B.S. degree from Seattle University and performed graduate studies at the University of Washington. At Tudor Engineering Company's Seattle office, he is responsible for all projects in hydroelectric energy. He is a Civil Engineer—Tudor Engineering Company, Seattle, Washington.

International Perspectives Sessions

Session Ten

INTERNATIONAL PERSPECTIVES

Topic: Development Experiences

Chairman: Alan B. Jacobs
Chief, Energy Office
Agency for International Development
Washington, D.C. 20523

SMALL-SCALE HYDROELECTRIC POWER REGULATION: A COMPARATIVE VIEW

Peter W. Brown

Legal and institutional barriers to small-scale hydroelectric (SSH) development are among the principle impediments to development of this resource in the United States. The legal and institutional issues range from cumbersome and uncertain state and Federal licensing systems, an array of environmental protection statutes and regulations, to the monopsony market of privately-owned electric utility systems. However, significant public interests such as Federal protection of navigation and interstate commerce and protection of natural and historic places, plant and animal species and human life itself are reflected in these regulatory schemes. The difficult and critical problem is to make adjustments among the public interests enumerated above and the development of a relatively environmentally benign, renewable energy resource.

Other nations such as Canada and Norway, which are as sensitive about their environment and people's welfare as the United States, have considerable large and small-scale hydroelectric power sites and are planning additional development. Since the physical phenomenon of water flowing downhill and being impounded by a dam is identical and is likely to create the same series of environmental impacts in all countries, much can be learned from the Canadian and Norwegian experience in undertaking hydroelectric projects.

The United States experience will be compared and contrasted with the Canadian and Norwegian experiences at various critical stages of project development:

(a) Project review and approval.
(b) Environmental review.
(c) Power marketing (how do other electrical systems value the power from SSH).

ABOUT THE AUTHOR: Mr. Brown is Professor of Law at Franklin Pierce Law Center, Director of the Law Center's Energy Law Institute and principal investigator on a DOE contract to study and recommend policy options concerning legal and institutional obstacles and incentives to small-scale hydropower in the Northeastern United States. Mr. Brown has practiced law on Wall Street, been First Deputy Attorney General for the Commonwealth of Pennsylvania, and Chief Counsel to the Public Utility Commission of Pennsylvania. He is a graduate of Bowdoin College and Columbia Law School.

SMALL-SCALE HYDROPOWER GENERATION IN NON-OIL-PRODUCING DEVELOPING NATIONS: SOME POLICY ISSUES

Franklin J. Ahimaz

The industrialized nations are rapidly reaching the saturation level as far as the development of large multipurpose hydropower sites is concerned. The developing nations, on the other hand, have barely begun to harness this potential. Some developing nations also possess additional opportunities for small-scale hydropower generation.

Such developing nations, particularly the non-oil-producing ones, are faced with some policy questions: (a) should a developing nation follow the example set by the industrialized nations and commit its meagre financial resources to develop large-scale multipurpose hydopower sites, or (b) should it use its resources to develop and integrate several small-scale hydropower stations?

A national policy to develop small-scale hydropower opportunities (case b) needs to be explored further. Since a policy for small-scale hydropower (SSH) generation needs to be linked to national development, it is necessary to review how SSH can compliment the current strategies for national development.

The "top-down" approach to development is a highly centralized-coordinated strategy for development. The benefits of large-scale projects funded by the strategy are expected to "trickle down" to the masses. Unfortunately developing nations that subscribed to this strategy, find that the gap between the "haves" and "have-nots" has steadily widened. Thus, the trickle-down theory has not been an effective tool to national development.

The "bubble-up" approach to national development promotes citizen participation in the identification of their needs and the definition of programs to meet their needs. But the bureaucratic maze that shrouds the initiatives generated at the lowest levels, stifles the process that can bring these initiatives to fruition.

A mixed strategy that incorporates the best features of the "bubbleup" and "top-down" approaches to national development might be more relevant to developing nations. SSH that compliments the "modified bubble-up" approach to development can help create dispersed population centers across a developing country. Each center can become self-sufficient as far as the non-portable, non-renewable energy needs of the center are concerned.

ABOUT THE AUTHOR: Dr. Ahimaz received the undergraduate education in India, the M.S. degree from Bucknell University and the Ph.D. degree from Cornell University. As Professor and Director of the Division of Basic Studies, College of Engineering, Cornell University, he administered the Institution Building Program at Cornell and the Program on Policies for Science and Technology in Developing Nations.

SMALL DECENTRALIZED HYDROPOWER FOR DEVELOPING COUNTRIES

Ken Grover

The goal for the Agency for International Development (AID) is to improve the way of life for rural and decentralized populations of developing countries. A blending of technology and funding of demonstration projects has provided the methodology to achieve this goal.

The approach involves definition of need, usually accomplished by working through an on-the-spot AID office. Once the need is spelled out a consultant, specialized in hydropower, is chosen to work with the AID officer to do the following:

a) Develop an information package including maps, rainfall data, topography, etc.
b) Develop site selection criteria and quantify developable hydropower.
c) Choose one or more typical sites for installation of demo units.
d) Cost the AID portion, engineering and equipment supply of demo hardware.
e) Estimate local cost for installation by receiving country.
f) Analyze rate structure possibilities to yield cents per kWh.
g) Project increase in area disposable income from this electricity.
h) State the impact in terms of social, economic and cultural benefits.
i) Summarize a-h in a recommendation for funding the project.

ABOUT THE AUTHOR: Mr. Grover is a mechanical engineer, educated at R.I.T. and Cornell Universities with a major in Industrial Power. He authored, or co-authored 11 patents in process plants and power equipment, and spent 29 years in sales, service and engineering of process and powerplants with major U.S. engineering and construction firms. Prior to forming his own engineering and consulting company he was Vice President of Foster Wheeler International. He has acted as a consultant in hydro since 1970, to industry, foreign governments and AID. He is President, GSA International and G&A, Katonah, New York.

THE ROLE OF SMALL-HYDROELECTRIC POWER GENERATION IN THE DEVELOPMENT OF ENERGY MIX FOR THE PEOPLE'S REPUBLIC OF CHINA

Deng Binli, Mao Wenshen, Alexander A. S. Tseng, and Tu Zhaoxiang

China is rich in her hydropower resources. They occupy 15% of the total world hydropower. The latest survey shows that there are about 1,600 rivers in China with a total generating capacity of 580,000 MW (the total generating capacity now available in the U.S.), of which approximately 150,000 MW will be generated by using small hydropower units from the medium and small rivers.

Since 1958 China has constructed more than 80,000 small and micro hydropower stations. Most of them are built by the people's communes at the county level. At present, over 10,000 MW of small and micro-power generating units are produced annually. These generating units with a capacity below 500 kW account for more than 60% of the above members.

The supply of electrical power for local industry, small workshops for the application of grain drying, wood cutting, oil extraction, lighting and film showing, etc., are typical rural area loads. The use of small units is to avoid delay and costly initial large power stations with transmission, subtransmission and distribution network. The conventional large thermal units have efficiency of 33%. The long distance transmission and distribution of electrical energy add another 10% loss to the electrical energy.

The proper mix with the use of small-scale hydropower, methane gas powerplants, conventional medium size thermal plants will be the initial major energy development program. The large-scale hydro units, such as the 1,250 MW hydro stations with 300 MW hydro units have already been installed at many major river basins. The long range development of China's energy mix is designed to meet the present four modernization programs, within the year 2000.

ABOUT THE AUTHORS: Mr. Binli is a working member of the Electrical Power Department, Peking, China. Mr. Wenshen is a working member of the No. 1 Machinery Department, Peking, China. Both are members of the CSEE. Mr. Tseng received the B.S.E.E. from the National Central University, China, with further advanced study both in E.E. and I.E. at the Illinois Institute of Technology and Stanford University. Mr. Zhaoxiang received the B.S.E.E. from the National Central University, China. He is the Vice Director of China National Machinery and Equipment Export Corp., Peking, China.

Session Eleven

INTERNATIONAL PERSPECTIVES

Topic: Technology

Chairman: James Victory
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NEW TECHNOLOGY AND OPERATING EXPERIENCE WITH MODERN SMALL-SCALE HYDRO TURBINES

Nils Rømcke

In 1945, Norway was operating 1,800 powerplants with individual output of under 500 kW. During the "Fifties" and "Sixties" development has been concentrated on large output units. However, in the past few years, smaller turbine units have again become prominent in Norway as everywhere else in the world.

Soerumsand Verksted A/S, part of the Norwegian Kvaerner Group, has been producing water turbines since 1904. Early in the 1970's before the world oil crisis, Soerumsand Verksted started a turbine development built up with years of experience in manufacture and in the field. Followed by radical standardization of the machinery, the development led to the introduction of a new generation of small turbines, which gives the customer maximum flexibility of operation.

Examples will be given from practical operating experience with different designs and materials in Propeller, Francis and Pelton-type turbines. Solutions offering reduced operating and maintenance costs will be emphasized.

Small turbines are not generally subject to frequency governing demands—therefore offering large savings in turbine and control system constructions. Important considerations, however, have to be known in respect to overspeed and pressure rise at load rejection conditions.

At a certain combination of head and flow usually different types of turbines could be employed. The author gives guidelines for selecting the optimal turbine type in respect of arrangement, efficiency and costs. Particular points of view of the border in the low pressure area between the Francis and Propeller-type turbine will be emphasized.

ABOUT THE AUTHOR: Mr. Rømcke was educated at the University of Karlsruhe, West Germany, gaining a Masters Degree in Engineering. He is Manager of the Construction Department at Soerumsand Verksted A/S, and has been the project leader on the development of small turbines since 1970. He has experience in maintenance work with all types of turbines and has also worked with the construction of large Francis turbines at Kvaerner Brug A/S, Norway.

SMALL-SCALE HYDROPOWER: AN APPROPRIATE TECHNOLOGY FOR LESS-DEVELOPED COUNTRIES

Robert D. Kersten

Hydropower technology is on the shelf, and available now, of proven feasibility, both technically and economically, and presents a sound and rational energy solution from the environmental viewpoint. It is a technology which could be useful to the Less Developed Countries for the long term irrespective of the shift from abundant low-cost fossil fuel options or the development of more exotic alternate energy technologies.

The nature of water resources includes a distributive element which makes it ideal for rural development. The apparent shift in development policy from the traditional "top-down" industrialization approach to the "bottoms-up" reach-the-village approach requires decentralized applications of energy resources attainable through development of hydropower in many regions of the world. This application of a relatively simple appropriate technology could result in a shift in emphasis from goods to people and thereby result in a general "quality of life" improvement in the LDCs. Certainly modestly distributed hydropower developments could lead to increased food production, better utilization of indigenous natural and human resources, prevention of unemployment and urban sprawl through labor-intensive projects, offsetting of population growth by development, improved health care, and augment the role of education for better adaptation in overcoming the problems of LDCs through their own actions.

Consideration is given to implications of development of a renewable energy resource (hydropower) on general economic development, social and political framework or infrastructure, and enhanced potential of LDCs to provide for themselves. Emphasis is placed on meeting basic needs as opposed to achieving or maintaining More Developed Country standards. A brief comparison of hydropower project economics versus scale of development and several pertinent technologies is presented.

ABOUT THE AUTHOR: Dr. Kersten received the B.S. and M.S. degrees from Oklahoma State University and the Ph.D. degree from Northwestern University. As Professor of Engineering and Dean, College of Engineering, at the University of Central Florida, Orlando, he is responsible for development of professional practice oriented engineering curricula; special emphasis include environmental systems, energy systems, technology and social change, technology transfer and economic development. Dr. Kersten has experience with water resources development, hydropower studies, solar energy research and petroleum production and transportation, including recent field experience in Central America.

MICRO-HYDRO AS AN APPROPRIATE TECHNOLOGY IN DEVELOPING COUNTRIES

R. J. Armstrong-Evans

By the turn of the century the mechanics of waterpower were well established and it was mainly improvements in mechanical governing which occupied designers for the next 30 years.

A totally new approach was pioneered by my father in the late 1940's and is now the basis of "electronic load control governing." This system facilitates the use of very simple turbines, while maintaining a high level of governing and at a fraction of the cost of traditional plants. Over thirty of these systems are running and have been for many years with virtually no maintenance. The concept is now being extended in many developing countries because virtually the whole plant can be built with minimal facilities. This extension work is with the Intermediate Technology Development Group who is involved with the setting up of small industries in the developing world.

We have identified several totally different approaches to microhydro, each of which is valid in the correct context. The smallest projects which are usually undertaken by the major companies is about 1 MW, unless it consists of a group of schemes. Below this size many of the most successful schemes are being built by agricultural engineering firms or at the lower end by individual engineers. At an even smaller scale plants of less than 5 kW can be built with virtually no site works at all and can be more economic than larger schemes, particularly when transmission costs are high.

I maintain that there are many economic and social advantages to the construction of thousands of very small plants rather than a few large ones.

ABOUT THE AUTHOR: The Armstrong-Evans family has been in hydraulic engineering for over 150 years and has been generating hydro power for 30 years. The author has built prototype and production equipment for use in the U.K. and developing countries for many years, and he runs a training project for micro-hydro engineers. He is Director, Evans Engineering, Priory Lane, Launceston, Cornwall, England, and a consultant with Intermediate Technology Development Group, 9 King Street, London WC2E 8HN.

SMALL HYDRO—A VIABLE ALTERNATIVE NOW

John S. Gladwell and Calvin C. Warnick

There is no single or simple solution to the world's energy problems, and if there were, small-scale hydro would not be it. But the planning process for an energy program should not overlook hydroelectric potentials simply because they represent individual small inputs. A number of significant factors are in their favor and should not be casually set aside.

It is clear that the increasing costs of alternative energy fuels will make hydroelectric projects much more economically attractive. Programs of small hydro developments could make badly needed marginal contributions to lagging energy growth in the immediate future and protect against dangerous shortages in the next few years. This may be particularly important in developing countries. In order to affect this, a concerted program of education and technology transfer must be implemented.

The present world economics favor the development of new hydroelectric facilities. These usually require major up-front input of capital, while relatively speaking the operations and maintenance requirements are a small portion of the annual costs. In particular, where dams already exist without generating capability, they need to be retrofitted. Even those sites requiring major new developments need to be more seriously considered. Hydroelectric energy technology is established and reliable. The potential for development of hydroelectric energy in most parts of the world far exceeds that which has been developed. And because the systems are small and relatively uncomplicated, local labor and expertise can be used to a much greater extent than some of the more exotic energy schemes. Nevertheless, it is clear that not all aspects are positive—and in particular the fact that the individual dams produce small amounts of electricity leads to problems of systems management.

ABOUT THE AUTHORS: Professor Gladwell has a B.S. in Business Administration from Trinity University, a B.S. and M.S. in Civil Engineering from Texas A&M University, and a Ph.D. in Agriculture Engineering from the University of Idaho. He is Director, Idaho Water Resources Research Institute and Professor of Civil Engineering, University of Idaho, Moscow, Idaho.

Professor Warnick has a B.S. in Civil Engineering from Utah State University, an M.S. in Civil Engineering from the University of Wisconsin, and a diploma in Hydrology, International Course in Hydraulic Engineering, Delft, The Netherlands, 1970. He is Professor of Civil Engineering, University of Idaho, Moscow, Idaho.

The authors have conducted several studies in small hydro and have written extensively on the subject, including the book "Low-Head Hydro." They have had considerable experience in the technology of hydroelectric energy development.

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DEPARTMENT OF THE ARMY
INSTITUTE FOR WATER RESOURCES, CORPS OF ENGINEERS
KINGMAN BUILDING
FORT BELVOIR, VIRGINIA 22060

REPLY TO
ATTENTION OF:

WRSC-IWR

30 June 1980

Dear Waterpower Registrant:

Publications from Waterpower '79 are becoming available. The first in a series of three is Waterpower '79: Executive Summary, a copy of which is enclosed. The remaining conference publications are the Waterpower '79: Abstracts and the Waterpower '79: Paper Proceedings. The abstract book is currently in final printing and a copy will be mailed to you as soon as possible. The Paper Proceedings will soon be available at a 25% discount to conference registrants.

All conference registrants desiring the 25% discount should indicate so by sending a post card to the Institute for Water Resources, Kingman Building, Fort Belvoir, Virginia 22060. Upon receipt of your request for discount, IWR will verify your registration and return to you a discount certificate. The certificate must be attached to your order as the Superintendent of Documents will have no way to identify registrants without the discount certificate. Your actual order with the discount certificate should be sent to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Sincerely,

James R Hanchey

JAMES R. HANCHEY
Acting Director